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In this monograph dealing with the suitability of electrically powered systems to emerging architectural trends, emphasis is upon the relationship of mechanical systems to overall building design. Topics disc ssed are--(1) All Electric Systems are Right for the Times, (2) Electric Systems Enlarge Freedom of Design, (3) Approaching the Question: All-electric or Not? (4) Heat Conservation in a Circular School, (5) Control by Each Tenant, Any Time at All, (6) Lighting Heat Trapped for Re-use at Windows, (7) Environmental Control with Minimum Intrusion, (8) Space Savings at Marina City, (9) Glossary of Electric-environmental Terms, (10) System-types Available for Environmental Control, and (11) Choosing a System to Suit Design Requirements. (RH)

# NECA
ELECTRICAL DESIGN
**GUIDELINES**



# ALL-ELECTRIC CONCEPTS FOR ARCHITECTURE

**The first in a series of monographs on electric environmental control, this article takes a new approach in dealing with the suitability of electrically powered systems to emerging architectural trends. Emphasis is upon the relationship of systems to overall building design.**



## ALL-ELECTRIC SYSTEMS ARE RIGHT FOR THE TIMES

The all-electric building is here — growing in number and degree of sophistication. Architects and others are learning that, just as with any architectural design problem, electric environmental-control must be examined in all its aspects — cost, space requirements, amenities, relationship to the overall architectural concept, prestige, and so on. There are no absolutes or simple answers as to which approach to environmental control is best.

Until fairly recently, most all-electric buildings — apartment buildings, small commercial buildings, motels, schools, houses — used simple room-by-room or relatively inflexible zone-by-zone heating and air-conditioning installations. For these building types, it is apparent that minimum first cost, design simplicity, minimum construction time, and the availability of accurate energy cost predictions are of prime importance. Obviously, the number of such installations is bound to increase.

In the last few years the picture has changed. The all-electric concept has been applied to *all* building types in every area of the country. The main impetuses for this have been recent advances in equipment and systems' technology, as well as more favorable rate structures. Many more architects, recognizing the advantages of all-electric environmental-control, have felt that there are strong reasons for exploring the full potentials of the concept, using more sophisticated and complex systems. On the one hand, the architect may desire a more exacting degree of thermal performance. On the other hand, he may desire a higher degree of system centralization in order to reduce the number of wall penetrations required for air intake and exhaust or to reduce the number of air-conditioning equipment locations. Almost without exception, these more sophisticated systems, in which electricity is the sole energy source, are far simpler to design, install and operate than their counterpart systems using fossil fuels to produce heat energy.

Still another factor enhancing the all-electric approach is the trend toward larger and larger predesigned packaged systems and ancillary components. These predesigned systems and packages and their attendant control systems are most readily available when they are all-electric. This approach, in the optimum case, centralizes manufacturer responsibility at one source. Going one step further, single responsibility can be assigned to the electrical contractor as the prime contractor for the system. When the mechanical aspects of the total system served by electric power as the single energy source become relatively more complex, the electrical contractor is still of prime importance, but these complex central systems require much more in the way of job supervision and coordination by the architect and his consulting engineer.

Beyond the favorable trends in technology and power rates that favor all-electric buildings, there is the salient fact that *most buildings today are all-electric in any event,* except for the source of energy for heating. Electric power usage per square foot is continually increasing for lights, office machines, communications equipment and audio-visual aids, vertical transportation, various kinds of automated equipment and equipment for in-plant feeding, and of course air conditioning. It is logical to go one step further and investigate the overall advantages of *total-electric* environmental systems.

Not only are architects specifying higher levels of light, but they are using light in a wider variety of ways. One of these is to combine lighting and air conditioning to enhance the value of interior space relative to the perimeter space. Until recently, the heat from lights had been allowed to enter the rooms, adding unnecessarily to the air-conditioning system load. In addition, this valuable reservoir of available waste heat from lights was not drawn off to be used to produce any useful heating effect and simultaneously improve the performance of the lamps. Many systems have been developed to recapture this heat and utilize it economically. In most cases, the system elements involved are part of what may be termed the "electric ceiling."

In any building, whether it is all-electric or not and regardless of the number of footcandles involved, the ceiling and its lighting elements are a fundamental statement of one of the architect's principal interior design concepts. Here again the fact that responsibility and field co-ordination can be centralized with the electrical contractor means that the architect can achieve greater control over the design and its installation.

It may seem that there is a bewildering array of all-electric systems. However, if these are examined in the context of fundamental concepts, it is apparent that very little new knowledge is needed for understanding various possible systems and the manner in which they can be applied. Some of these are covered in the next section of this monograph. It also might seem that the engineering requirements of the all-electric approach could infringe on overall architectural goals. But this is not so. For instance, it would be a fallacy to assume that recovery of lighting heat is a necessary ingredient to make an all-electric system economically feasible. The type of lighting the architect feels is most appropriate to a given situation may not make heat recovery (a) practical or (b) necessary. Admittedly, the concept of high footcandles, applied indiscriminately, is reasonably questioned by the architect. The architect's main concern is to have the right light in the right place. High footcandle levels in most cases are compatible with this concept; this point will be examined in more detail later.

# ELECTRIC SYSTEMS ENLARGE FREEDOM OF DESIGN

Space advantages

The all-electric equipment and systems currently available can reduce the total building volume required for heating and cooling system components and more efficiently utilize the space that is required.

Among the more obvious space advantages, of course, is the elimination of the boiler, its ancillary equipment, and the stack. At most, a central equipment room will house refrigeration apparatus which often works as a heat pump.

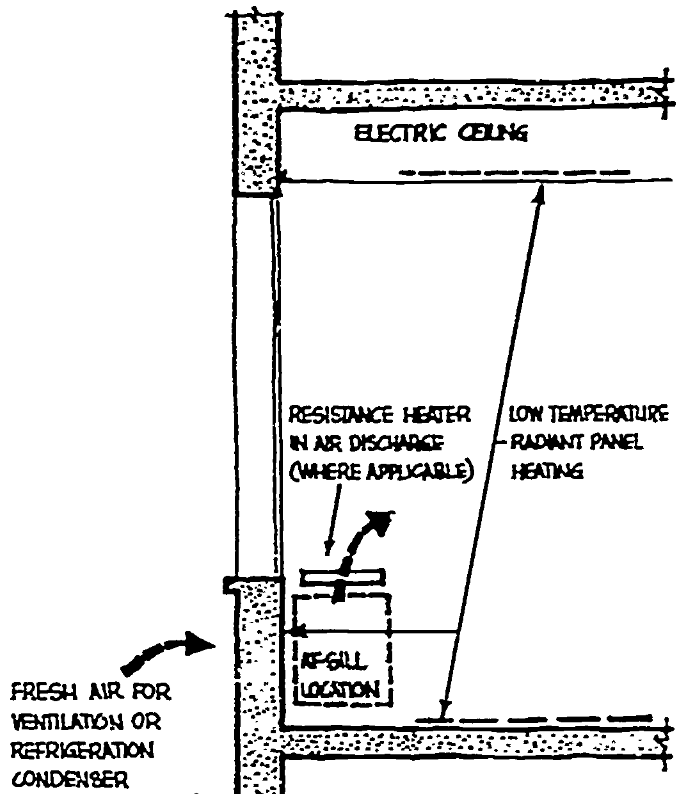
The all-electric approach, by allowing a greater degree of decentralization of equipment, a wider choice of equipment location, and a reduction in the size of some of the components themselves, cuts down the total volume of building required.

The amount of shaft space and ceiling space required for ducts can be reduced. As an example, perimeter heat losses in a building might be counteracted by an electric baseboard system, with space cooling, some heating, and ventilation being provided by a ducted system from the building core. A comparable result could be achieved by using small unitary heating-cooling units for the perimeter zone and multiple smaller ducted systems for interior zones.

By decentralizing the energy-transformation equipment (i.e. refrigeration apparatus, resistance heaters), normally wasted space (or space having little or no rental value) can be utilized to house it. Such spaces are the roof, the building core, stairwells, closet space, hung ceilings, etc.

### Greater flexibility in temperature control

It can be easier, and is always more efficient thermodynamically, to provide a greater degree of individual temperature control with all-electric systems. This is particularly true in the case of the heating effect in a fully air-conditioned building. For example, simple resistance heating units in the room spaces will always be controlled by individual room thermostats at very low installation cost because the action is simple and direct. Contrast this with the various complications of zoning and mixing used with water systems, which have expensive control valves and thermostats. Also, with decentralized packaged equipment used room-by-room, it is possible to run most units on standby or shut them off when rooms are unoccupied, while permitting other units to operate as usual.




**Simple all-electric perimeter-area heating: In the initial phases of the architect's design, he is concerned with what kind of exterior wall he will use and how this interacts with the perimeter heating system. With the all-electric approach, he has the greatest range of heating possibilities. Types of sill-area heating equipment shown are: ■ radiant panels ■ through-the-wall unitary air-conditioning or heat-pump unit (single or split system) ■ unit ventilator (provision for add-on cooling optional) ■ unitary air conditioner or heat pump with water-cooled condenser ■ hot water to fan-coil unit from all-electric package.**

### Lighting as an element of electric space conditioning

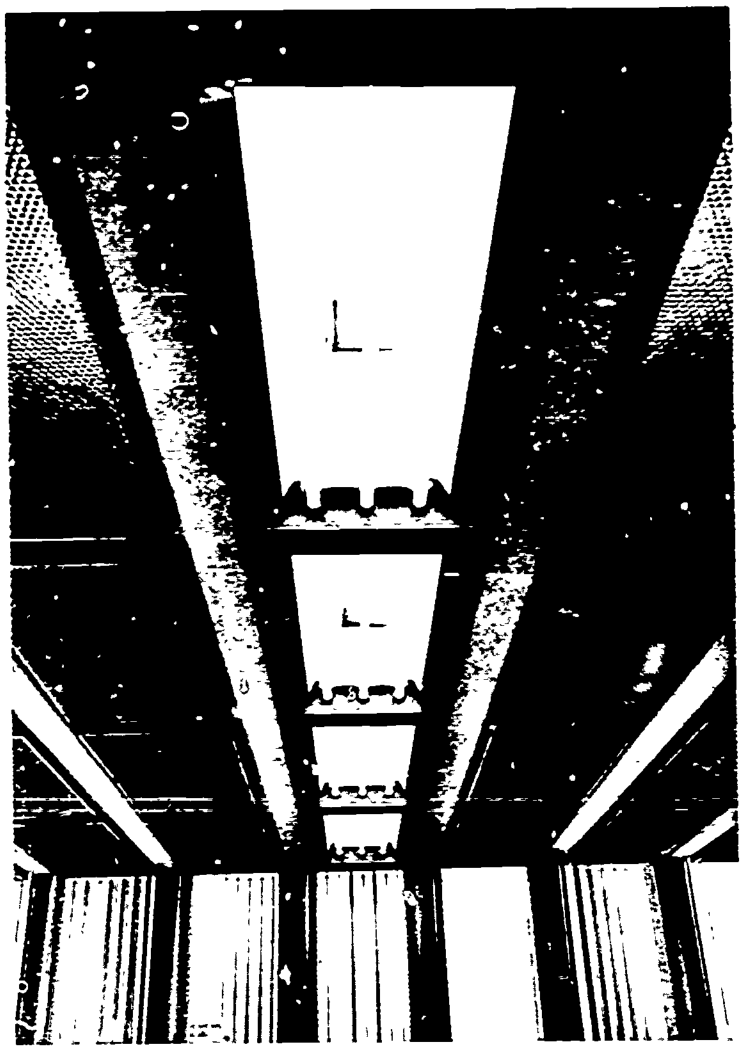
Not only are higher levels of lighting being employed in today's buildings, more lighting is being used in general as part of architectural design. The public expects the higher footcandle levels provided by quality systems for various work situations in office buildings, schools, and industrial buildings, and for appraising merchandise in stores. In fact, brightly and comfortably lighted spaces are one of today's indexes of progressive management.

Taken together with other uses of electricity, this increased use of light for all purposes means that: (1) total electrical consumption for a building will be much higher than in years past, with a consequent lower cost per kilowatt hour, and (2) the available heat energy from lights, in addition to that from other electrical equipment, can be turned from liability to asset by reutilizing it for temperature conditioning of space. Such reutilization may take the form of: (a) reheat to adjust the temperature of cooling air going to individually controlled spaces; (b) tempering of outside air in wintertime for ventilation purposes, or (c) pickup by a heat pump system for redistribution of the "waste" heat to some portion of a building needing it.

## APPROACHING THE QUESTION: ALL-ELECTRIC OR NOT?

"How can I justify using electricity, a relatively expensive energy source, to heat this building?" This question undoubtedly is the initial one the architect asks himself when he considers the "all-electric" concept for the first time. He readily accepts the need for electrical energy to power air conditioning, fans, and pumps. But on a straight Btu for Btu basis the cost comparison of heating with gas or oil versus heating with electricity may seem lop-sided in favor of the former.

Cursory evaluation, however, ignores the fact that most air-conditioned buildings are almost entirely all-electric in any case, except for the heating. The cost of providing electric power supply and distribution for heating in addition to air conditioning could be almost insignificant. A simplified example: a building could just as well be space conditioned year-round with room-by-room heat pumps as with room-by-room air conditioners and a separate heat supply. The heat pumps would be using the same power supply (perhaps with a slightly larger wire size) as the air conditioners alone. In fact, economics could even dictate the choice of heat pumps, provided that the architect had considered a few building design details that improve heating economics in cold climates. This example might seem to oversimplify the case; nonetheless, the important point for the architect to remember is that a direct Btu to Btu comparison is never a valid comparison — even where simple resistance heating is used. To illustrate: when a building goes all-electric, the cost per kilowatt-hour for the normal base electrical load is reduced, just as the heating rate is lower.



Higher levels of lighting in the electric ceiling call for greater attention to ceiling brightness control and to heat removal. This is accomplished in the Marina City office building by parabolic-shaped louvers for light shielding and air exhaust for lamp-fixture heat control and recovery of heat.

**Building design for reasonable thermal efficiency**

There are no handicapping design restrictions for the architect doing an all-electric building. But as with any building material or system, there is a basic design discipline to be followed for best application of the approach. Obviously it is good practice to use well insulated building enclosures. Double glazing helps. (A prime reason for using double-glazed windows in the first place, however, is to help prevent occupants' "cold-radiant" loss to the glass areas.) When the sash are operable, t e architect should specify that they be tight fitting. Infiltration of outside air at building entrances and at other openings should be minimized. The consulting engineer should design for "controlled" use of outside air for ventilation; outside air should be kept to a minimum consistent with code values or satisfactory performance. Of course, these suggested improvements also serve to reduce the air conditioning load. In any event, the all-electric building can look just like any other building; the above good-practice recommendations will help make the all-electric building economically sound.

**Engineering considerations that make the all-electric approach practical**

Inherent with the all-electric approach are a number of engineering and economic factors which relate to: (1) reduction of overall electrical energy costs, and (2) energy costs directly chargeable to heating. These include:

1. The factor of time — electrical energy is used only when and where needed.
2. Heat energy multiplication — the heat pump delivers far more energy than is used to power it.
3. Electric thermal-conditioning systems have insignificant energy flow losses.
4. There are no central energy plant standby losses.
5. Outside ventilation air is used only when needed and in minimum amount.
6. Temperatures are set back at times other than actual occupancy.
7. Heating loads and load peaks can be determined realistically, including the effect of heat storage within the building mass.
8. Lower-cost off-peak power can be exploited.
9. The system can be carefully designed to sequence the starting of heating and ancillary equipment to reduce demand peaks. (In residential occupancies such as apartment buildings with room-by-room systems and other small loads under approximately 25 kw, the demand peaks level themselves out because of a large diversity factor and thus are of no concern to the utility.)
10. A credit can be taken on electric heating costs because of the reduced billing of lighting, summer air conditioning and other miscellaneous loads. A lower base-rate schedule is made possible by use of electric heat.
11. Cost of the electrical installation may be reduced due to different termination points for the utility company's service feeders, etc.
12. Total annual cost, comprised of owning costs and operating costs, in particular, can be carefully and properly evaluated. This is especially important because the cost of direct energy for an electric heating system is a greater part of the total cost than the cost of direct energy for a fossil fuel system is for its total. (Fossil fuel systems have indirect costs for operation of pumps and other auxiliaries). This evaluation is most important when the heating is by straight resistance units, which have very long life and practically no maintenance cost, and there is no heat recovery or heat pump application.
13. Computerized analysis and prediction of energy demand and usage are within available methodology and may be desirable to determine feasibility.
14. The heating-cooling system designer should be aware of and consider the use of statistical probabilities as applied to both seasonal and daily temperatures; temperatures at the high and low ends of the range occur infrequently. (The lowest temperatures are always late at night or in the early morning. The frequency and duration of these temperatures closely follow prediction by a standard probability curve relation.)

(Continued on Page 16)

Principles at work: Douglas MacArthur Elementary School, Southfield, Mich.

# HEAT CONSERVATION IN A CIRCULAR SCHOOL

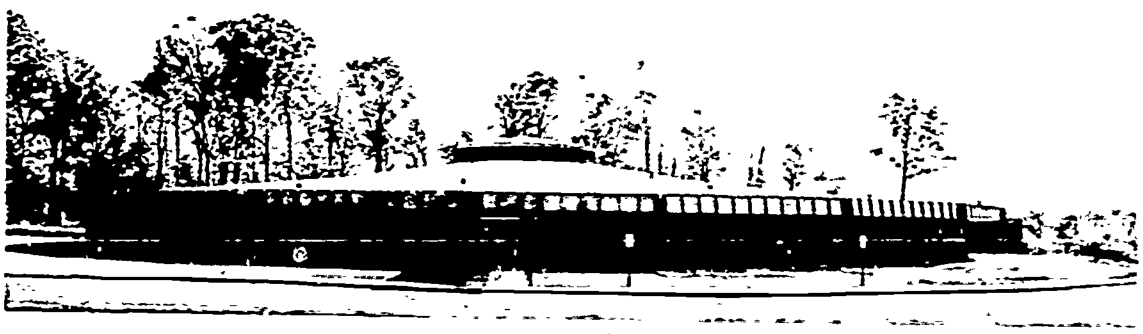
A circular plan—derived basically from educational requirements — works advantageously for the all-electric thermal environmental control system in the 47,000 square-foot Douglas MacArthur Elementary School. Cost of the school, which is in suburban Detroit, was only $13.59 per square foot.

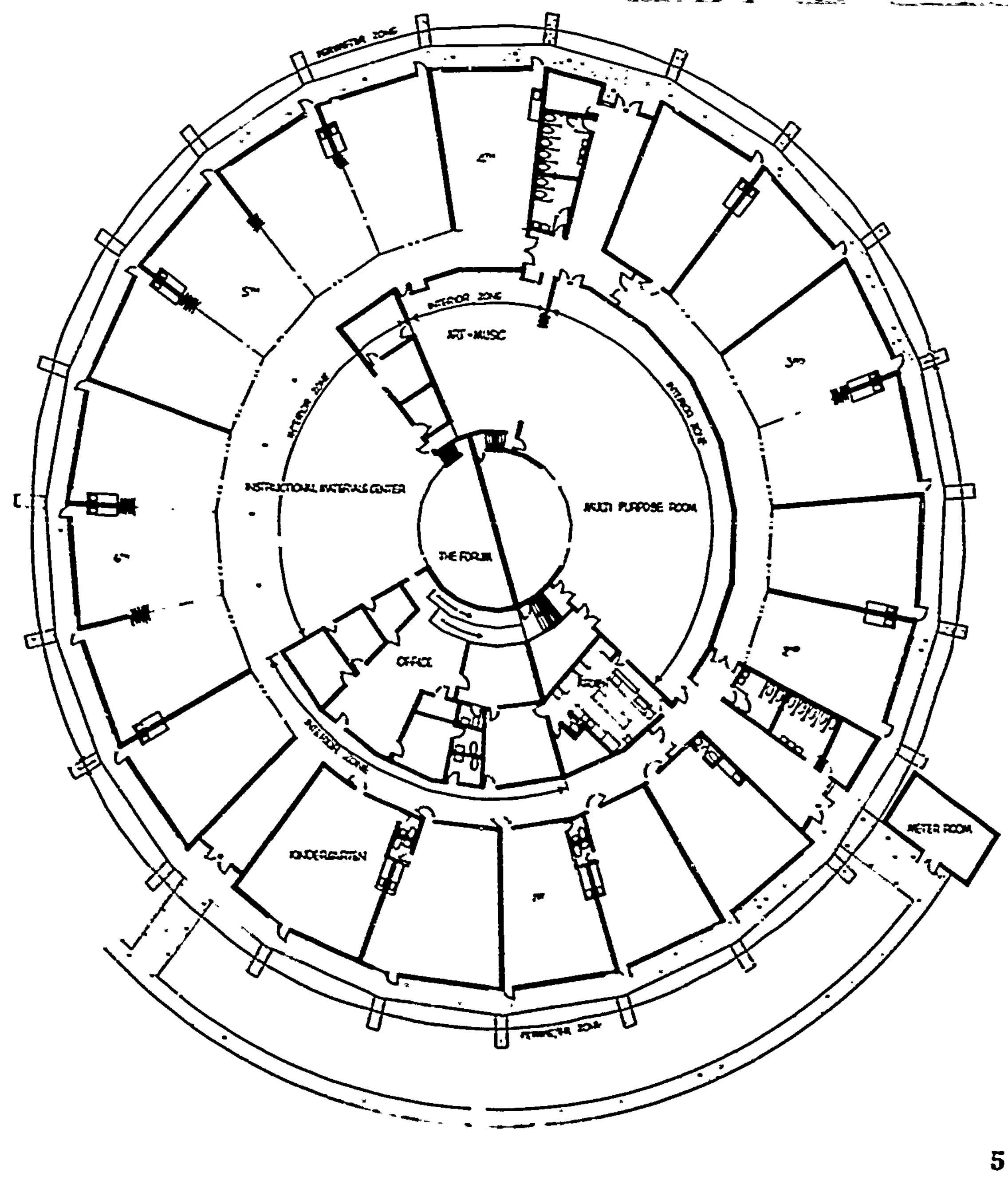
The basis for the design is a core containing an electronic learning-center and an instructional materials center, with 20 classrooms radiating out from this core. At the center of the core is a 40-foot diameter hub which: (1) at roof-top level, houses air-handling equipment for the ventilating system in a so-called "service pod" or penthouse; (2) at grade level, provides a raised platform for use as a stage, and (3) below this platform, houses a production center for the school's electronic learning-center.

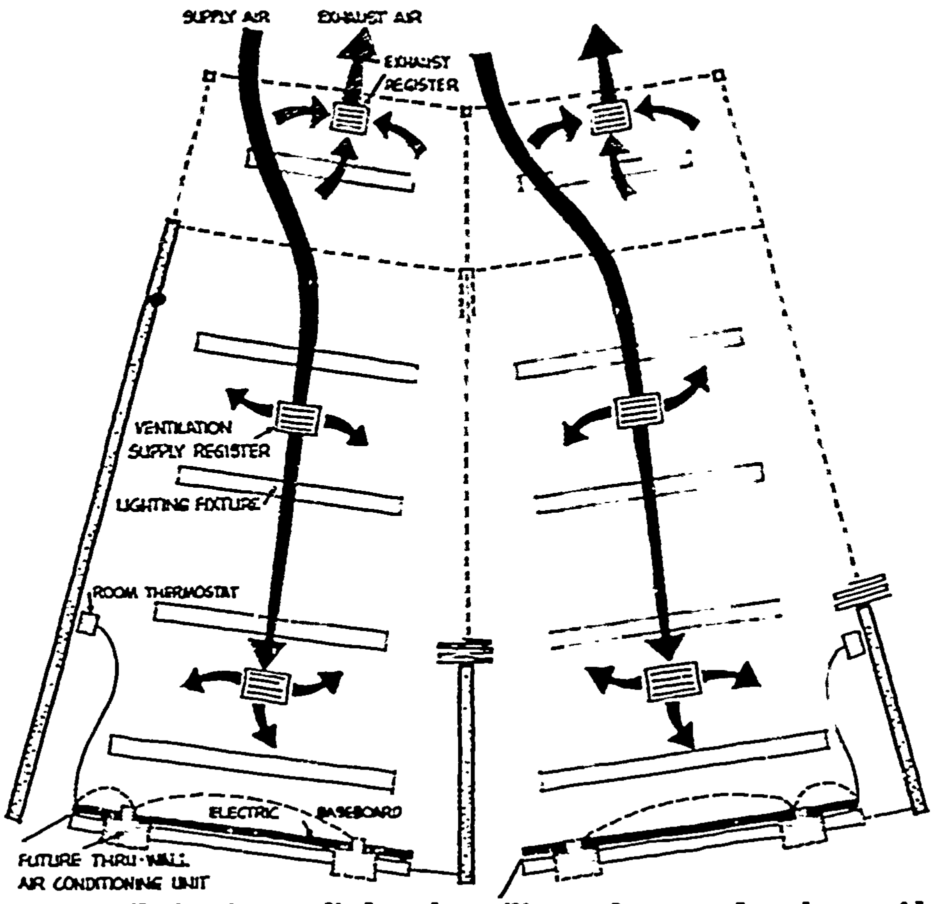
One of the big advantages of the circular plan is that it helps minimize heat loss, since a circle has the least perimeter for a given area. The use of glass in the exterior wall is in keeping with current educational and architectural philosophies that sufficient glass is needed to enable students and teachers to maintain contact with the outdoors, but that it should be so arranged as to minimize distraction. Thus, the architect, Joseph St. Cyr, ran a 12-in.-deep band of glass just below the overhanging roof around the entire pe-

*Prior to the preliminary planning of the MacArthur School, we were requested by the owner's Building and Grounds Department to analyze and report on any system that would guarantee a minimum maintenance factor, minimize noise from ventilating equipment, and increase the fresh air ventilation within the school. We investigated all forms of heating systems and struck on the use of electric radiant and duct heaters as the simplest, most economical form of heat for this very compact structure. We also suggested using the regenerative wheel as a fuel-saving device and method of allowing us to increase the ventilation up to 100 percent.*

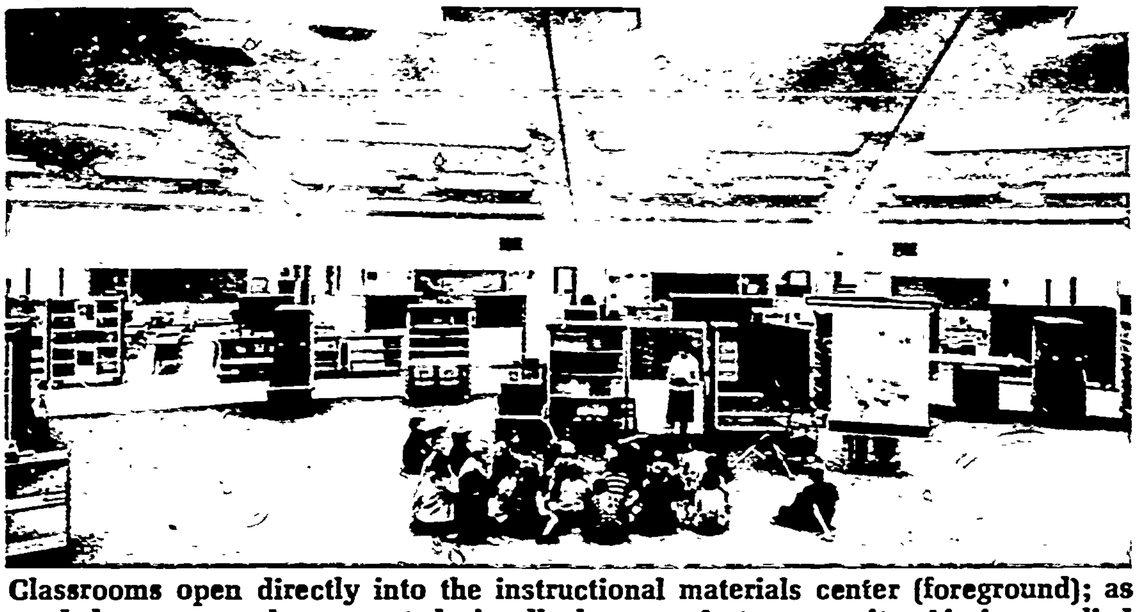
*Joseph St. Cyr, AIA*



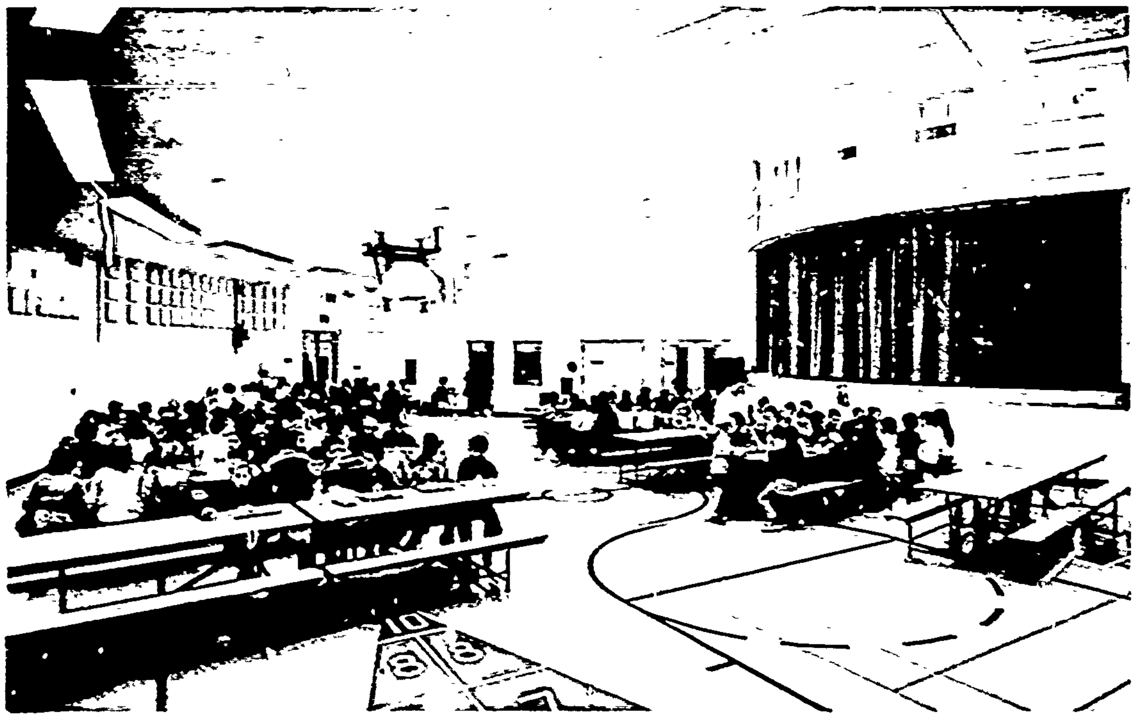





**Classroom ventilation is supplied at the ceiling and returned at the corridor. Heating is by perimeter electric baseboards; cooling by through-the-wall air conditioners.**



**Classrooms open directly into the instructional materials center (foreground); as needed, areas can be separated visually by use of storage units. Air is supplied to center through ceiling diffusers and returned through perimeter grilles.**



**The multi-purpose room, as well as the instructional materials center, has a raised stage area, shown above at the right. Equipment pod is located above the stage.**

rimeter. In addition, there is a three-foot-wide vertical strip of fixed glass and a glass-paneled door in each classroom. The building is fair indication that all-electric schools are a long way from needing to be "windowless."

A noteworthy feature of the thermal control system of the Douglas MacArthur School is that it recognizes an inherent characteristic of schools — a necessarily high ventilation rate, compared with other building types. This ordinarily wasteful process was avoided in the Douglas MacArthur school by passing exhaust air through a seven-foot-diameter regenerator wheel installed in the penthouse, which extracts heat from the air before it is dumped. Heat-absorbing aluminum mesh in the regenerator wheel picks up the waste heat, and, as the wheel revolves slowly, transfers the heat to the incoming ventilation air. With an air change rate of 2½ air changes per hour 15-degree outside air is brought up to 63 degrees when the inside air temperature is at 75 degrees.

The service pod atop the hub of this circular building is in an economical location for the central equipment that furnishes ventilation air. Supply and return air ducts could be primarily radial, cutting down on the weight of sheet metal required and making ductwork simpler and easier to install.

The thermal control system also recognizes that in today's school buildings, with their high lighting levels, high electrical equipment usage, and improved insulation, rooms must be cooled, rather than heated, during most of the occupied hours.

The heating system consists of thermostatically controlled baseboard heaters in each room. When the building is unoccupied, these electric heaters keep the building at a constant 65 degrees; before school opens, the temperature is raised to 70-72 degrees. Once the building is occupied, the temperature has to drop to 7 degress below zero before any additional heat is required — the balance being made up by body heat, lights, and equipment heat. When the outside temperature is above 30 degrees, the school is cooled with unheated outside air.

Cooling is provided for the core of the school on warm spring and fall days and during the summer by a 20-ton central air-conditioning unit, mounted in the penthouse space along with the regenerator wheel and ventilation fan. Enclosures (two per classroom) are provided near the top of the perimeter masonry wall for future installation of room air conditioners, which will be necessary when the school is used 12 months a year.

A large percentage of the classrooms have open planning. Except for the kindergarten and first-grade rooms, the classrooms open directly into either a corridor or into the instructional materials center. With 4th, 5th and 6th grade classrooms, radial separation is by operable partitions. Separation of classrooms from the corridor or the instructional materials center, when desired, is accomplished by movable storage cabinets — at other times these cabinets can be used wherever desired for convenience and to establish class groupings.

Lighting is fluorescent, with individual rheostat controls at each teaching station to adjust the lighting level to suit the particular teaching activity. Maximum lighting level is almost 200 footcandles at desk-tops and 100 footcandles at the chalkboards.

Installation costs for domestic hot water were cut by installing small instantaneous electric water-heaters in the kitchen, custodial closets, and in boys' and girls' washrooms.

Outside design conditions: summer 95 F. d.b., 75 F. w.b.; winter —10 F. d.b.

Total connected load: 339 kw.

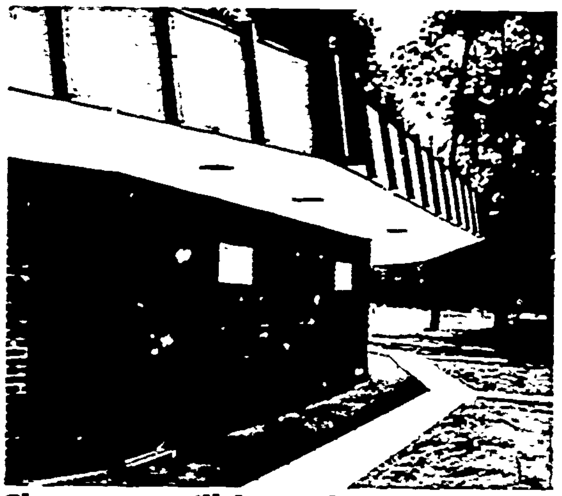
Maximum billing demand: 246 kw, Dec., 1966.

Note: Electric rate is special rate for all-electric schools, $175 per month for first 10,000 kwhr, plus 1.5 cents for each additional kwhr. School not yet turned over to school board.

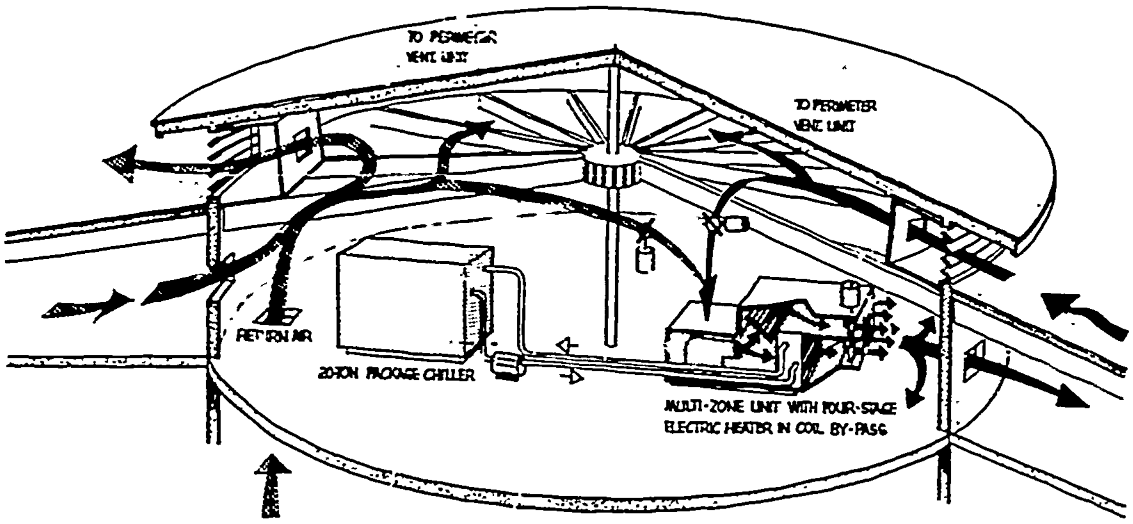
Building: Douglas MacArthur Elementary School, Southfield, Mich.

Architect: St. Cyr Architect and Associates, Inc.

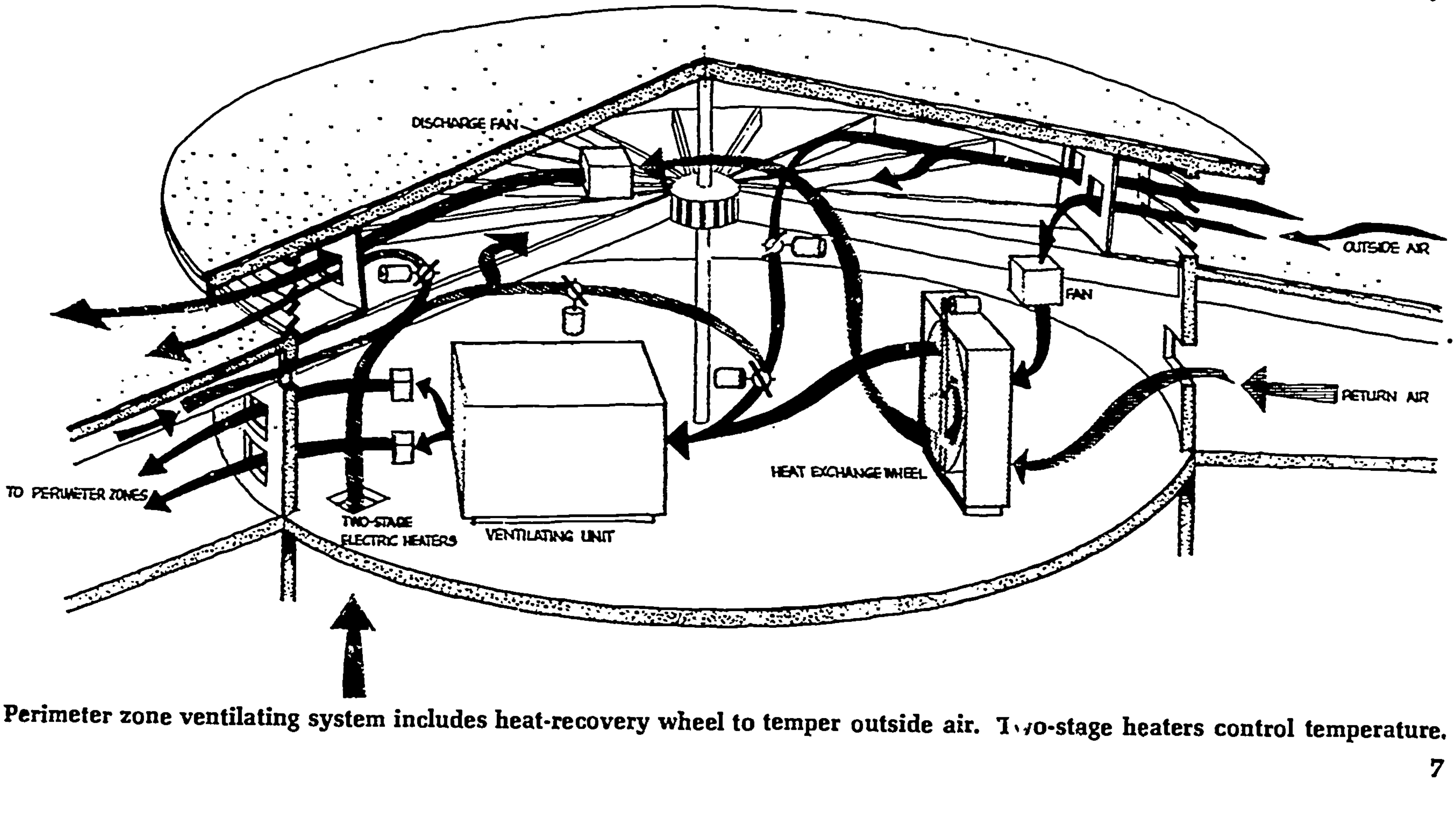
Electrical Contractor: Ove Hansen Electrical Contracting



Classrooms will be cooled by through-wall units. Glass is in strip at the top of brick wall and in vertical lights.




Interior system cools with 20-ton package chiller, with tempering by four-stage heater. Offices and instructional and multi-purpose areas are zoned separately.




Perimeter zone ventilating system includes heat-recovery wheel to temper outside air. Two-stage heaters control temperature.

# CONTROL BY EACH TENANT—ANY TIME AT ALL

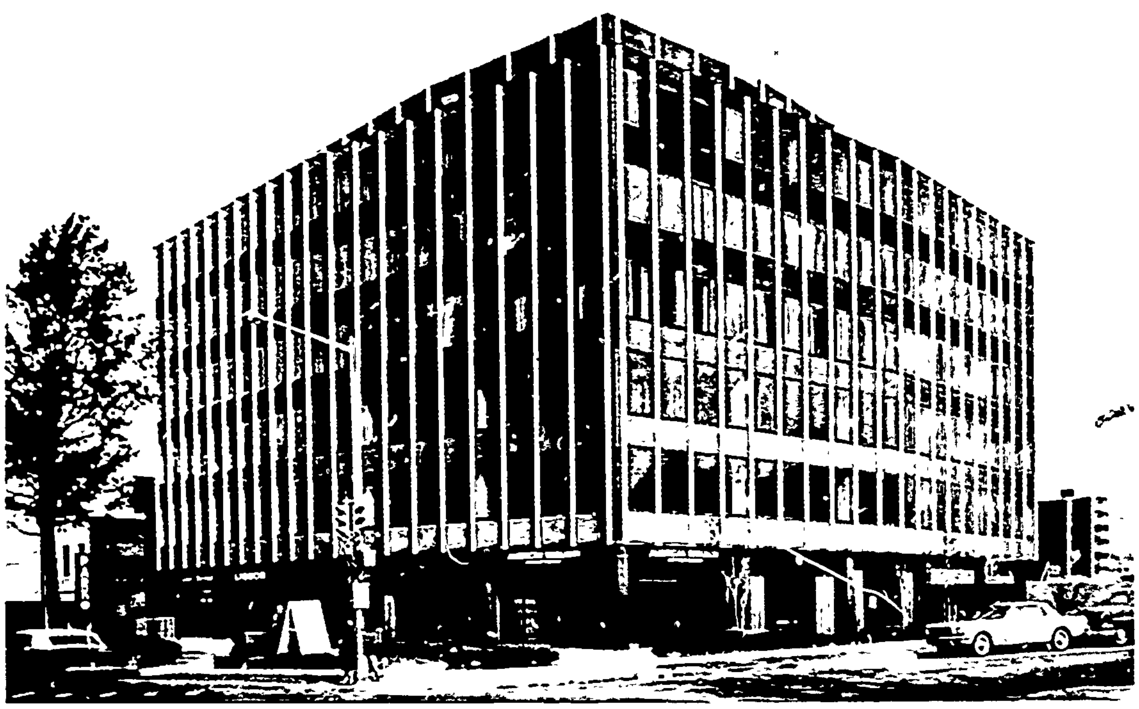
With office buildings going up at a fairly rapid pace, and building owners and managers consequently operating in an increasingly competitive market, the architect and his consultants must come up with more than merely attractive facades and lobbies to attract and hold tenants. The owner of the Freudberg Building felt that he should rent his offices to the younger businessman — the fellow on his way up who finds it necessary occasionally to work nights or weekends. With this rental premise as a design consideration, the architect and his consulting engineer had to chose a comfort-control system that could operate outside of normal working hours without being an economic burden for the owner.

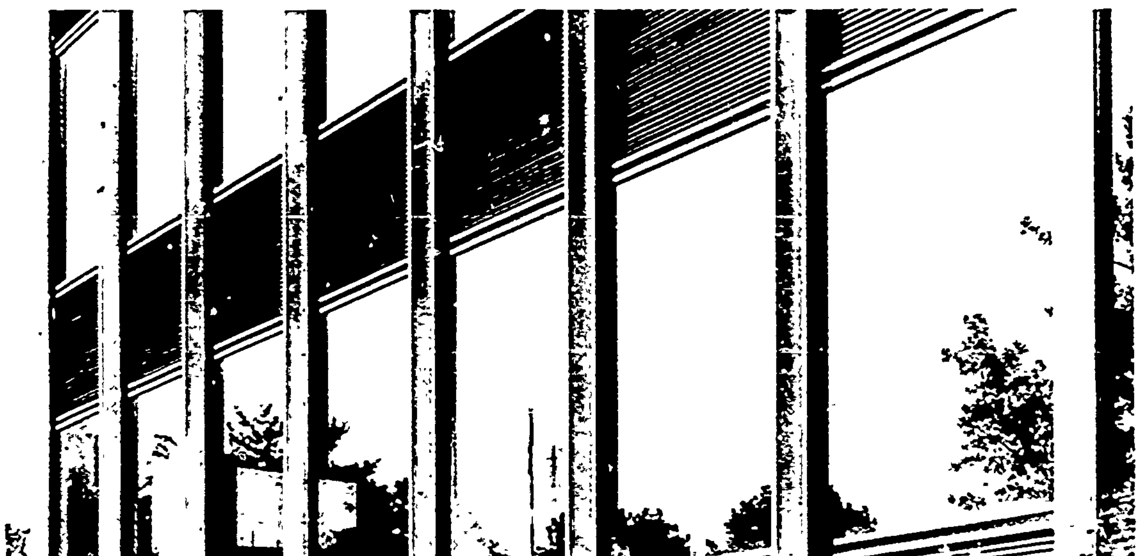
The system selected for the modified-octagonal-shaped Freudberg Building comprises 200 incremental room-by-room heating-cooling units for the perimeter offices and a 100-ton central air-conditioning system for interior offices and corridors. The 200 incremental terminal air conditioners automatically go on night set-back after normal working hours, but they can be reactivated by tenants who work overtime.

The incremental units are "supervised" by a central control device called Triple Overriding Dual Control. The hours of tenant occupancy are set up on a seven-day time clock, which automatically starts the units in random sequence every morning, Monday through Friday, and

*We elected a thru-wall, incremental, heating-cooling system for the Freudberg Building in order to provide maximum flexibility for 168 hours a week. This building by its location, nature, and size is attractive to younger organizations and others which are not necessarily functioning on an eight-hour-day basis. Absolute control placed in tenants' hands offers such tenants an additional amenity. We feel certain that the exterior treatment of this building and use of the continuous louvered spandrels will stimulate the imagination of other architects and engineers to solve air-intake louver problem with better and better results. We ourselves are working in this same area on other projects.*

*Alan J. Lockman, AIA*



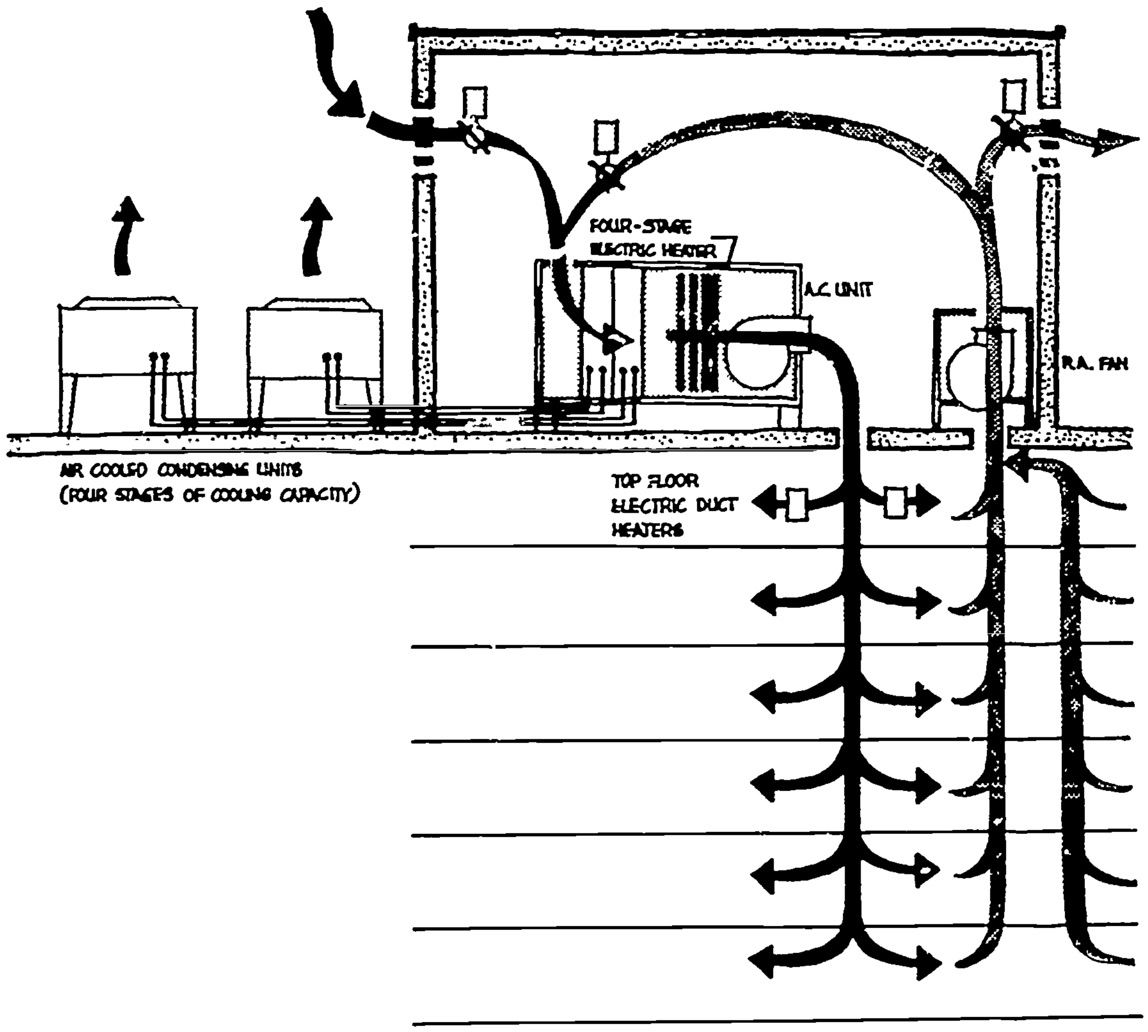


**All spandrels are louvered, giving an overall, banded pattern to the facade, and allowing location of air intakes for room units at any position along wall.**

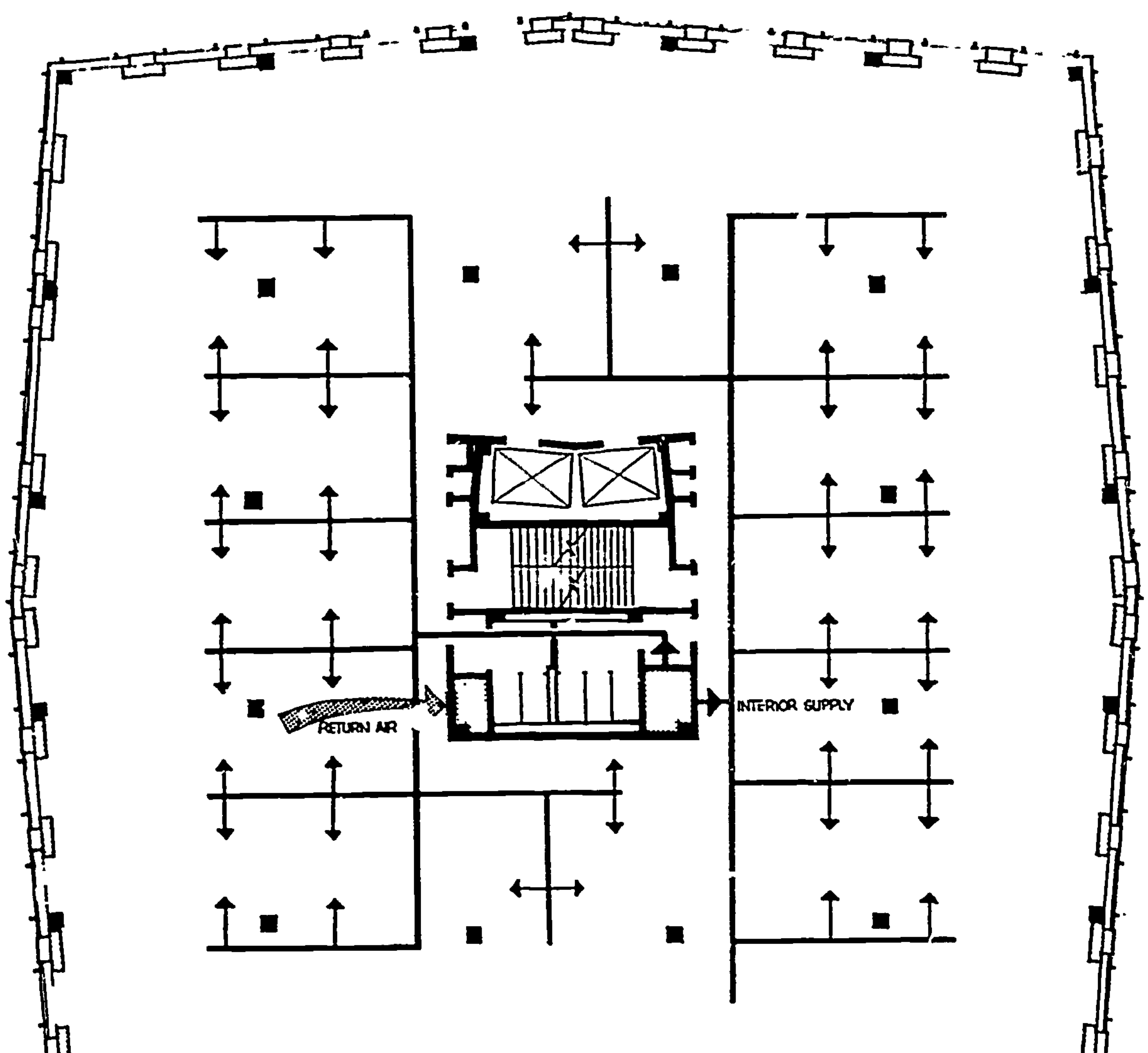
switches it to night set-back condition after quitting time. From then until 5 a.m., room temperatures are maintained at 55-60 degress in winter. However, a tenant working late can reactivate his individual air conditioner merely by pressing the override button on the control panel. While the time clock could give instructions to the equipment at half-hour intervals, it is set up now only to "check" on the equipment at 6, 7, and 9 p.m. and 12 midnight. The incremental units are sequenced to go on 50 at a time at half-hour intervals in the early morning hours to bring offices back up to 70 degrees. At 5 a.m. the first 50 are instructed, the next 50 at 5:30, and so on.

To counteract heat loss through the roof, the interior zone duct system on the top floor has small duct heaters. The central system on the roof has resistance heating for morning warm-up. Most of the time, of course, it is cooling rather than heating.

The attractive curtain wall of the Freudberg Building consists of double-glazed, heat-absorbing glass and anodized aluminum louvered spandrels. The continuous louvered spandrel section makes location of the incremental units inconspicuous. The incremental units are installed under fewer than half of the windows now; they could be shifted to meet a changed interior layout.




Air for the building's interior zones is cooled by roof-mounted air-conditioning equipment. Electric duct heaters on top floor balance heat loss through the roof.




Interior space conditioning of the Freudberg Building is supplied by a roof-top central unit. Incremental cooling units in the offices also provide two-stage heat.

- Outside design conditions: summer 95 F. d.b., 78 F. w.b.; winter 0 F. d.b.
- Connected load (winter maximum): 1060 kw.
- Maximum demand to date (90 per cent occupancy): 590.4 kw for Feb., 1967.
- Anticipated average annual electric rate: approximately 1.5 cents/kwhr.

- Building: Freudberg Building, Washington, D.C.
- Architect: Lockman Associates
- Mechanical and Electrical Engineers: Shefferman & Bigelson
- Electrical Contractor: Walter Truland Corp.

# LIGHTING HEAT TRAPPED FOR RE-USE AT WINDOWS

As new light sources have been introduced and old ones improved, and new methods of light control developed to direct light rays and control glare, footcandle levels in common usage have grown increasingly larger. The simple fact is that people seem to like a lot of light in working situations, provided that the light is of good quality - that is if glare is controlled and brightness contrasts in the room do not exceed good practice recommendations. As tasks vary in degree of difficulty, so do the footcandle levels that permit a high degree of visual performance. The reason people like high footcandle levels, however, probably is due as much to the fact that high lighting levels make rooms seem bright, cheerful, and clean as it is to the improved lighting offered for visual tasks.

Since energy costs per footcandle have decreased over the years, the prime limitation on higher and higher footcandle levels is the heat produced by lamps and ballasts. Allowed to enter the room, this heat may be expensive to remove. It is only recently, however, that studies have been made and techniques developed for removing lighting heat at the source rather than letting it enter the room. When lighting heat is removed from the fixture either by exhaust air or by cooling the fixture with water, the waste heat can be captured and reused by the heating and air-conditioning system to supplement normal energy used for heating or to provide temperature by the reheating of cooled supply air.

Footcandle levels of 150 to 250 footcandles are not uncommon these days, and, at the higher levels, needed quantities of conditioned air can be kept at reasonable levels by removing the heat from lamps at the source. Size of refrigeration equipment can be correspondingly reduced.

Building #3, Executive Park East, Atlanta, has 239 2-by-4 foot water-cooled fluorescent fixtures in an of-

Ground floor of office building is leased to one firm, top floor to another. Large windows on top floor have louvers on east (shown here), south, and west facades.

Recessed fluorescent fixtures, providing 100 footcandles, have integral water tubes for taking heat away from lamps. Louvers at exterior wall utilize this heat in winter. In summer, louvers pick up sun heat which, with lighting heat, is rejected.

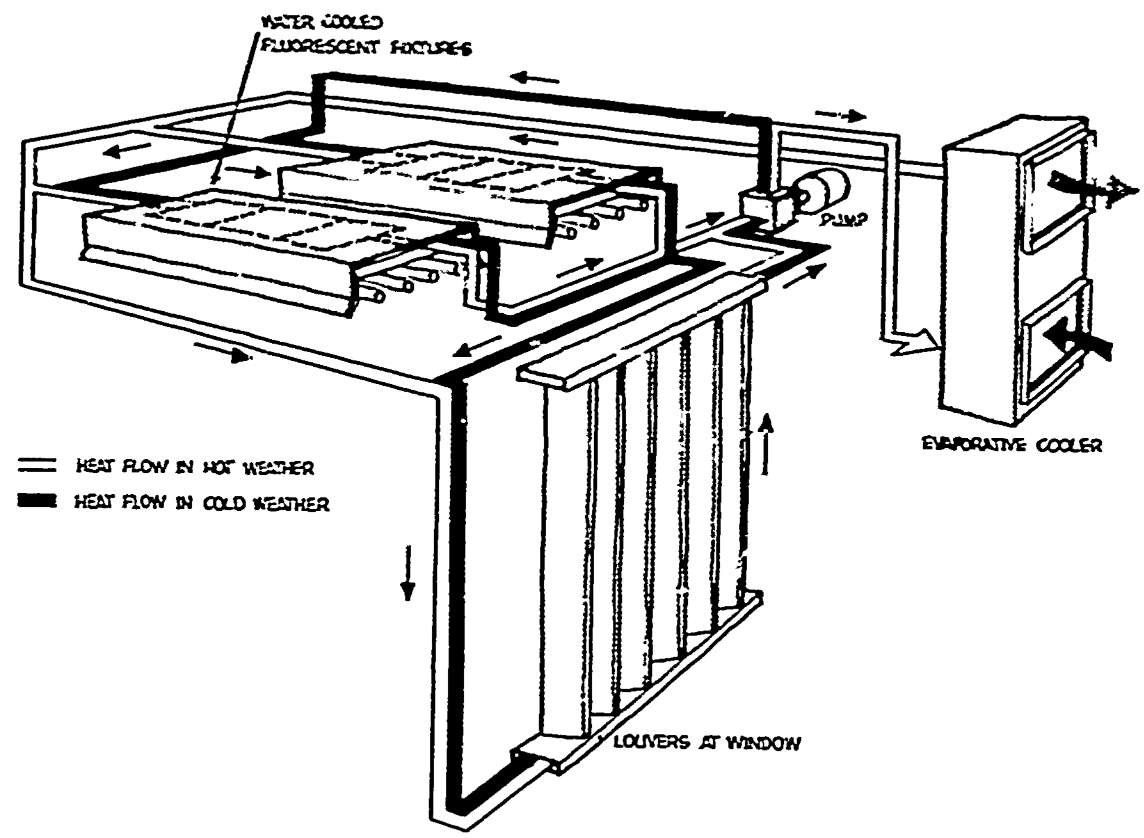
*The heat removal-utilization system was selected based on prior knowledge of what the potential of the system was. The office had considered the use of the system on previous projects. The design criteria of 100 footcandles of illumination and large solar glass loads indicated that serious consideration should be given to use of the system in this building. A study of savings in installed refrigeration tonnage and operating costs indicated favorable total economics, therefore the system was installed. We find the architectural effect of the variable louvers at the windows to be pleasing.*

*Preston S. Stevens, Jr., AIA*

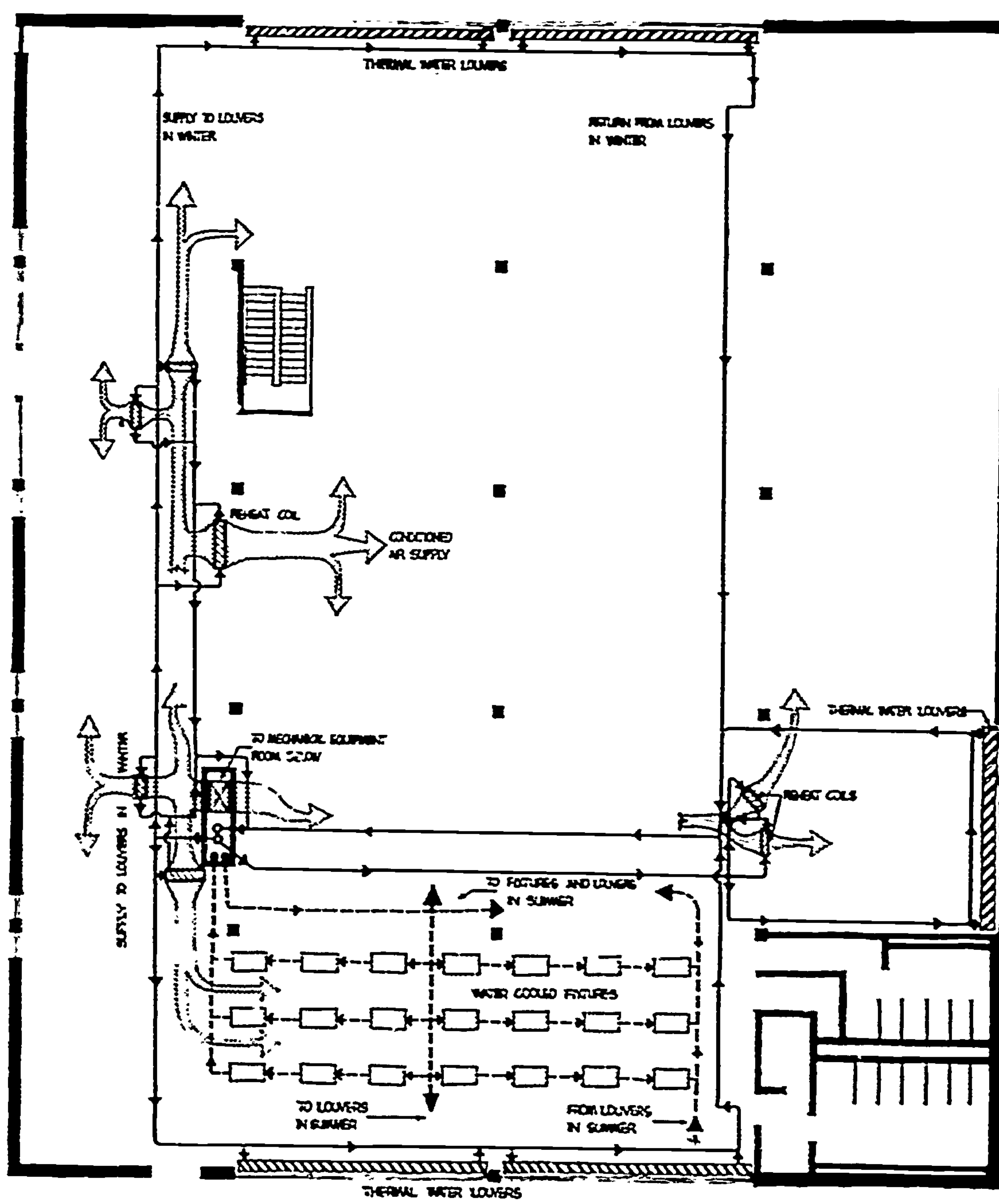
fice area slightly less than 125-feet square, providing a lighting level of 100 footcandles. Even at 100 footcandles, it pays to reclaim from the lighting fixtures the energy that does not go into producing light (with fluorescent lamps 17.5 to 19 per cent of the electrical energy input comes out as light). The luminaires have embossed water tubes integral with the aluminum reflector housing through which non-refrigerated water is circulated. As the water circulates, it absorbs the heat from lamps and ballasts.

The fixture cooling water is maintained at not lower than 77 F. and not higher than 85 F. Fixture cooling water itself is not used for reheat directly; rather, this heat is "pumped" to a higher level in the condenser to provide 125 F. water for reheat. The reheat coils may temper incoming cool supply air in summer, or in winter actually provide heating for perimeter zones. Basically the refrigeration equipment works as a heat pump, furnishing chilled water for cooling and warm water for reheat. Since fixture heat is removed by the water-cooled fixtures, air supply grilles are located to give proper air distribution and air returns are located where convenient.

Water-filled louvers behind windows on several facades intercept the sun's heat. They also can work in reverse to counteract the cold radiant effect of glass in the winter.




During cold weather, heated water from lighting fixtures flows to window louvers to counteract heat loss. In summer, it goes to an evaporative cooler.




Perimeter heat losses in winter are offset by redistribution of lighting heat to thermal louvers and to reheat coils, which serve as temperature-"trimming"-controls. Outside air is tempered by heat-recovery. Little resistance heat is used.

Outside design conditions: summer 95 F. d.b., 76 F. w.b.; winter 10 F. d.b.
Maximum billing demand: 259 kw, Dec., 1966.
Minimum billing demand: 194 kw, May, Aug., Sept., 1966.
Average monthly billing: $965.02.
Average rate: 1.3 cents/kwhr.

Building: #3, Executive Park East, Atlanta
Architect and Engineer: Stevens & Wilkinson
Electrical Contractor: Bagby Elevator & Electric Co.

# ENVIRONMENTAL CONTROL WITH MINIMUM INTRUSION

An increasingly serious problem for architects and their consulting engineers is the physical co-ordination of ducts, pipes, lighting fixtures, and mechanical equipment with the structure; also the integration of mechanical elements and lighting with the ceiling.

Such co-ordination difficulties did not arise in the D.E.N.T. Building because, first of all, the four package heat pumps that provide either warm or cool air to the three subdivided areas of this two-story building are mounted on the roof out of the way. Secondly, the choice of a ventilating ceiling to deliver air to room spaces, meant that little ductwork was required and diffusers could be eliminated from the ceiling.

The architect thus could devote his attention to the selection of lighting fixtures and organizing them within the ceiling plane. Since there is much less going on above the ceiling than in the usual building, overall interior construction could proceed at a faster pace.

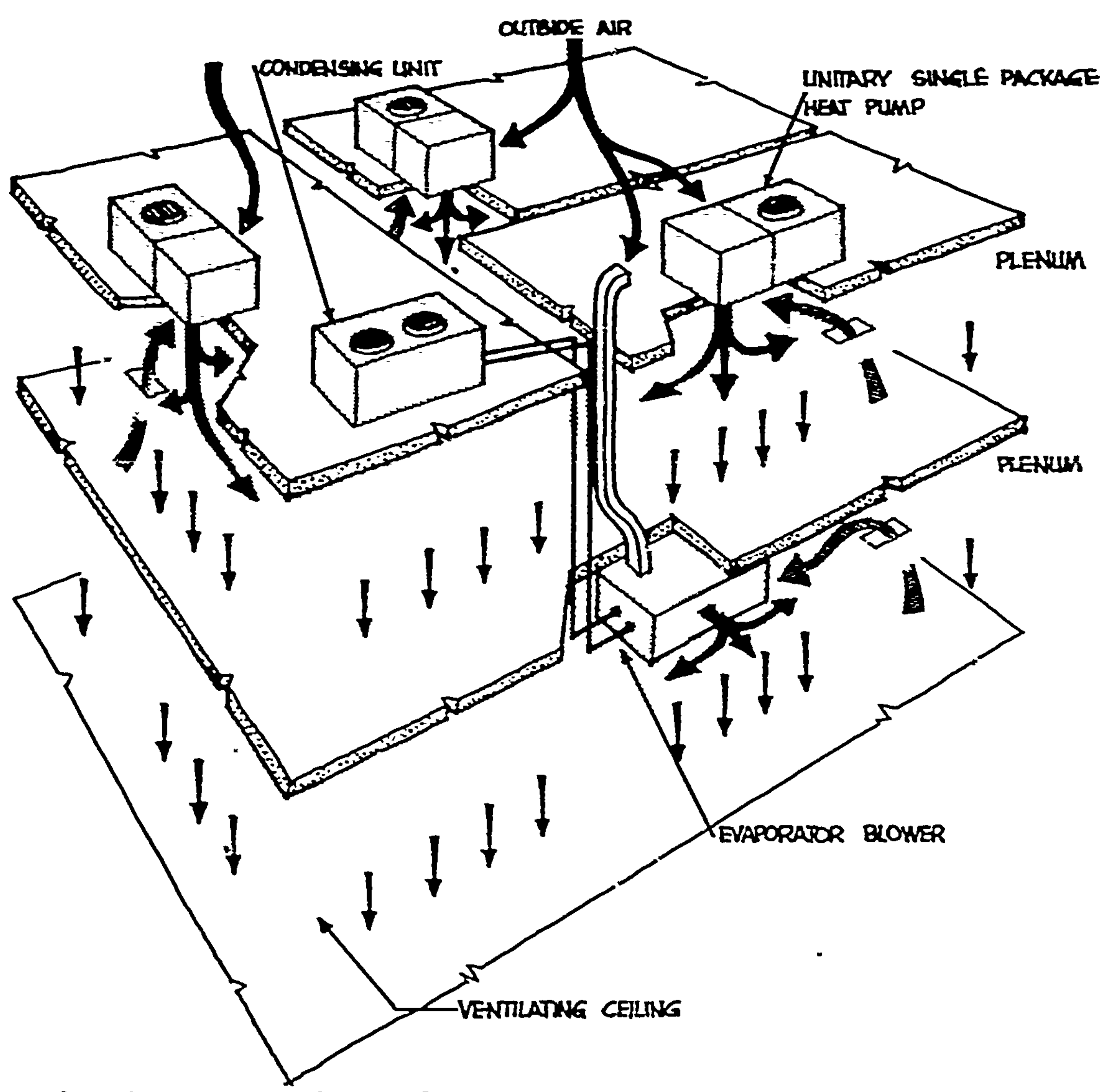
In medical clinics, overall lighting footcandle levels need not be particularly high. Obviously there should be sufficient light in the right places to give examination and office space a bright, clean appearance. But since the equipment which produces the most heat — examination lights, sterilizers, and the like — is close to the floor, there is no possibility of heat retrieval at the ceiling line. The ceiling need only perform its simple functions of supplying air, incorporating the lighting, and concealing the "hardware" and the structure; it need not be designed for heat retrieval as well.

Building: D.E.N.T. Building, South Charleston, W. Va.
Architect: Howard G. Johe
Electrical Contractor: South Charleston Electric Co.

Outside design conditions: summer 95 F. d.b., 75 F. w.b.; winter 0 F. d.b.
Average monthly billing: $129.11 (for three suites).
Average rate: 1.61 cents/kwhr; each suite is individually metered; loads are below point (30 kw) at which demand metering starts.

*The owner-occupants wanted a completely controlled environment. With well established medical practices, they desired convenient working conditions with no real compromises on cost. Hence, the building provides efficient working areas in a comfortable, attractive atmosphere. With efficiency as the keynote, a single source of heating and air conditioning was imperative. The ventilating ceiling system with electric heat pump sources has proven to be clean and comfortable. Supplemental electric resistance heat is required in three remote locations.*

*Howard G. Johe, AIA*




**Roof-top heat pumps with supplementary heaters provide either heating or cooling through ventilating ceilings. Evaporator-blower for lower level is installed there.**

# SPACE SAVINGS AT MARINA CITY

The convenience, amenity, and cost-saving features of all-electric living and working are especially well exemplified in Chicago's famed Marina City. Here in the twin 64-story residential towers are 896 electrically heated and air-conditioned apartments, as well as 180,000 square feet of electrically space-conditioned office area in an adjacent 10-floor office building.

Apartment heating is provided by baseboard heaters extending from column to column under the base of a full-height, double-glazed window which, together with the balcony door, comprises the exterior wall of each apartment. The baseboard has a capacity of 160 watts per lineal foot (546 Btu/hr), and this can be supplemented, if needed, by resistance-heating coils in the apartment air conditioner, which is set in the wall over the balcony door.

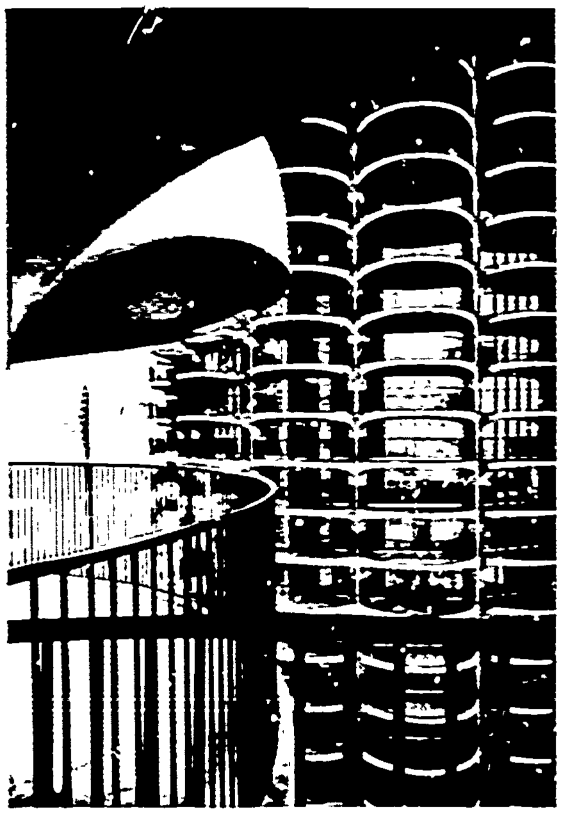
The apartments have complete electric kitchens, fast-recovery electric water-heaters, built-in bathroom heaters, lighting fixtures designed by the architect, ample convenience outlets and a weatherproof receptacle on each balcony. The heating and cooling equipment is operated from a single wall-mounted control (240-volt) in each apartment. This control has four switches — two to control the heating and cooling and two to control the air conditioner fan. The tenant may have the fan run continuously or work only when the heating or cooling unit in the air-conditioning unit is energized by the thermostat.

The cores of the apartment towers are under positive air pressure to prevent odors from seeping out into the corridors from apartments. The air supplied is removed through kitchen and bathroom exhausts. To maintain the core air at proper temperature, each apartment tower has two 42-ton heat pumps on the roof, along with air-handling equipment.

The apartments are better wired than the typical house. For example, an efficiency apartment has 12 circuits and a corresponding demand load of 19.5 kw, a two-bedroom apartment has 24 circuits and a corresponding demand load of 29.9 kw.

Probably the most electrically noteworthy feature of the office building is a 277-volt, 250-footcandle fluorescent lighting system. Parabolic wedge-louvers attached to the fixtures shield the workers' eyes from direct glare. The special heat-removal fixtures are designed to draw room air over lamps to maintain proper operating temperature and remove lamp heat before it has a chance to enter the room. Each fixture is connected to a small duct, and this in turn to an exhaust duct header.

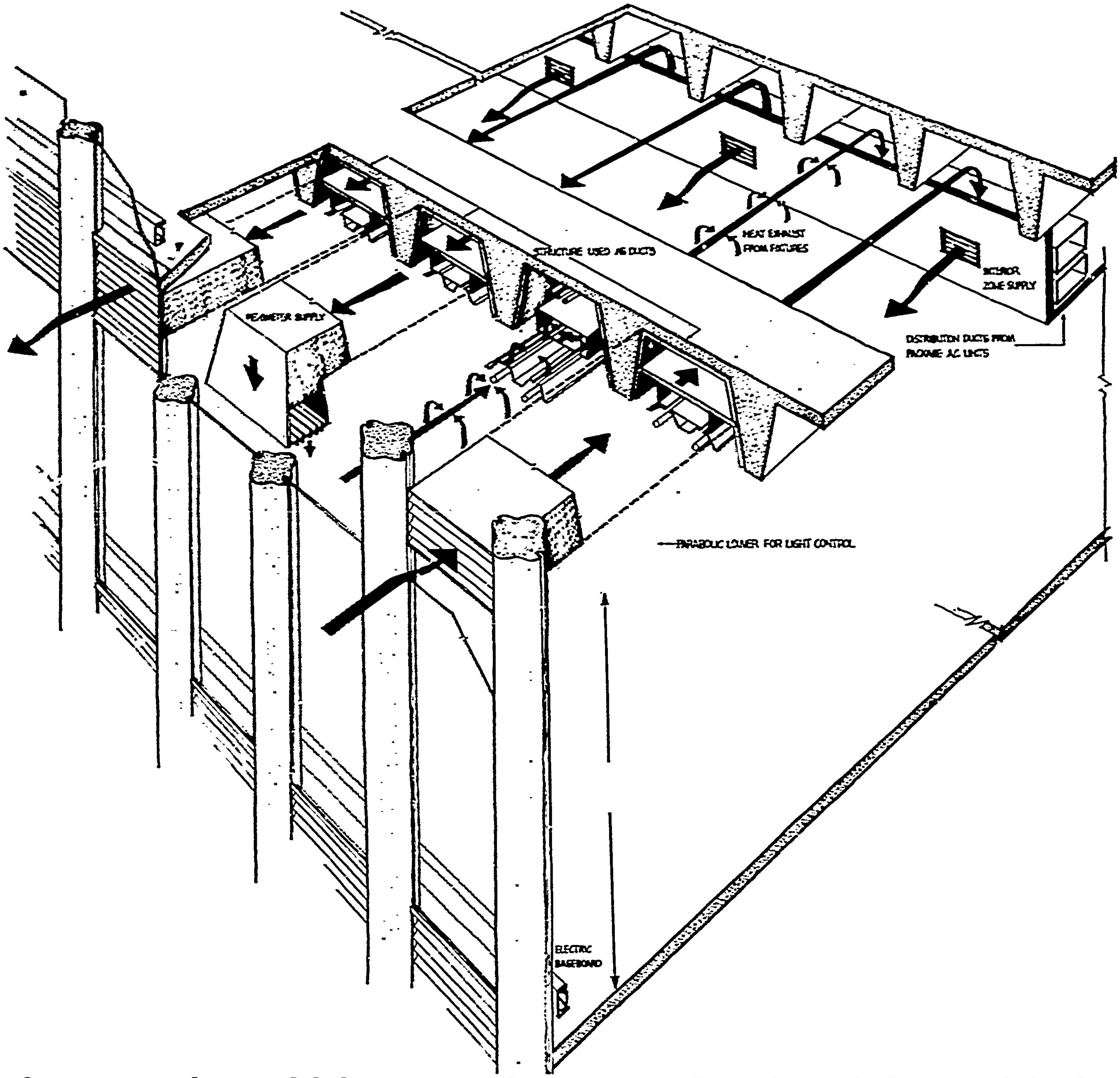
To prevent discomfort at office exterior walls in winter, baseboard electric-heating units have been provided. Because the under surface of



*A 12,000-volt vertical distribution system for the all-electric Marina City apartment towers gives us many architectural freedoms: freedom from air pollution by fossil fuels, freedom from labor problems, freedom from space allocations for bulky shaft risers and engines rooms, freedom from capital expenditures for major equipment. We enjoyed the planning flexibility in the extensive use of electricity — in the original economy of layout, and the economy of tenant changes. Viva volta.*

*Bertrand Goldberg, AIA*

**Entire thermal control for Marina City apartments is at exterior walls: electric baseboards are placed under windows, doors; packaged conditioners above doors.**



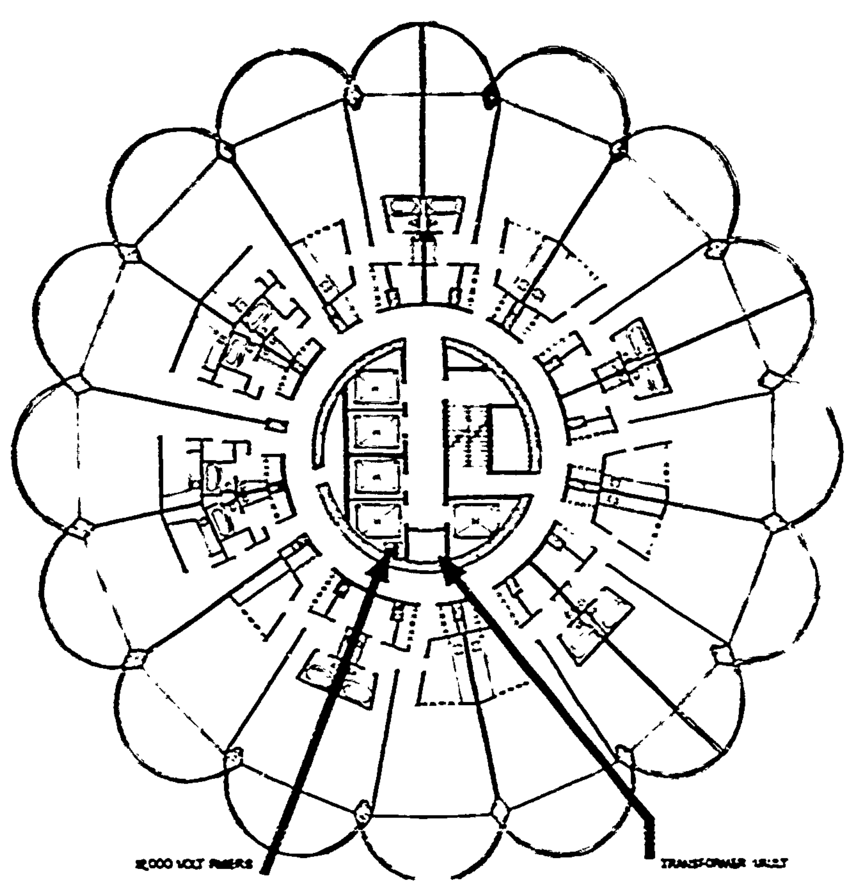

**One-way concrete beams work both as structure and air ducts in the office building. Louvered spandrels at the perimeter allow fresh air to be drawn in and vitiated air to be exhausted. Air is drawn through the lighting fixtures.**

**Offices have 250-footcandle lighting at desk tops. Lamps are shielded by louvers.**

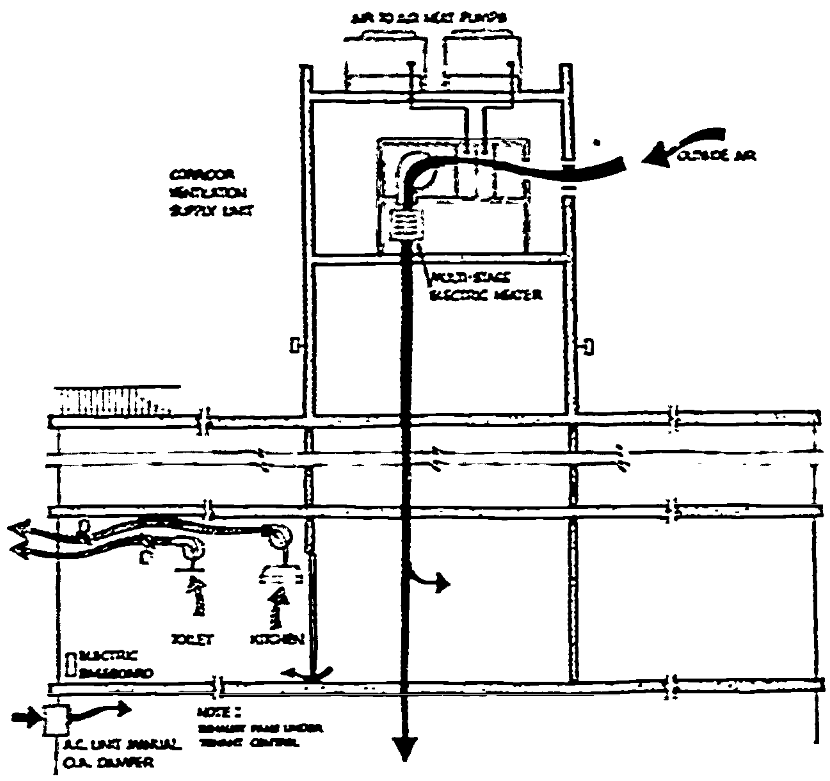
the lowest office floor is exposed to the outdoors, this floor has in addition to thermal insulation, 73 kw of heating cable to offset the floor heat loss.

A swimming pool in the same structure as the office building not only is heated electrically, but two of its insulated walls exposed to outdoor temperatures are heated by twelve 1,000-watt ceiling-mounted quartz infrared heating units. The walkways around the pool have 29 kw of heating cable.

More than 3,000 kw of connected load employed for snow melting is installed in the first two spirals of



Transformers, to step down voltage to apartments, and meters are on alternate floors of the two tower buildings.




Ventilation air for apartments is tempered by the roof-top heat pump system (supplemented by resistance heaters). It is distributed to corridors by branch ducts from the shaft. Kitchen and bathroom exhaust air is removed by small fans.

the parking ramps, at the base of the apartment towers and at the base of the office building (and in apartment balconies).

A unique feature of the power distribution in the Marina City apartment towers is the use of 12-kv risers serving 200-kva transformers on alternate floors, which in turn furnish 120/240-v service to the individual apartments.

By taking advantage of the all-electric concept, the architectural and electrical system design has been estimated to have saved the owner (Building Service Employees International Union) more than $2,000,000 in capital costs. This has been attributed principally to: (1) elimination of boilers, stacks, and auxiliary equipment and piping; (2) use of individual electric water-heaters in apartments, eliminating a hot-water riser system, and (3) installation of the 12-kv risers in the tower core to cut the size and quantity of wire and conduit.

Outside design conditions: summer 95 F. d.b., 75 F. w.b.; winter —10 F. d.b.

Average annual apartment billings and average rates: one-bedroom apt., $173.88 per year (1.766 cents/kwhr); two-bedroom apt., $275.27 per year (1.590 cents/kwhr). These costs are for all electric usage, including air conditioning.

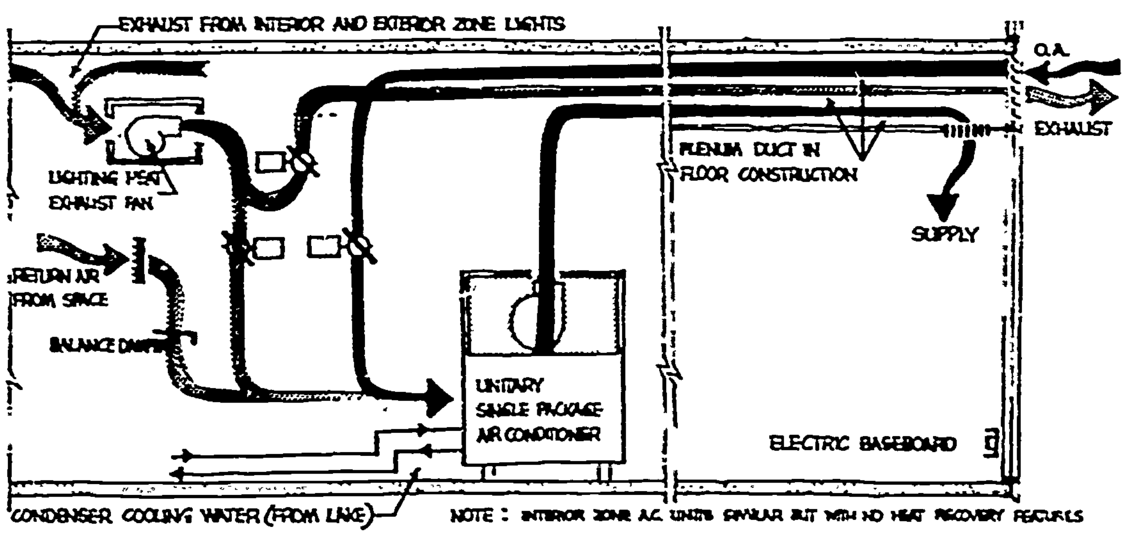
Maximum demand for the entire Marina City complex is 20,000 kw.

Building: Marina City Residential Towers and Commercial and Office Building, Chicago

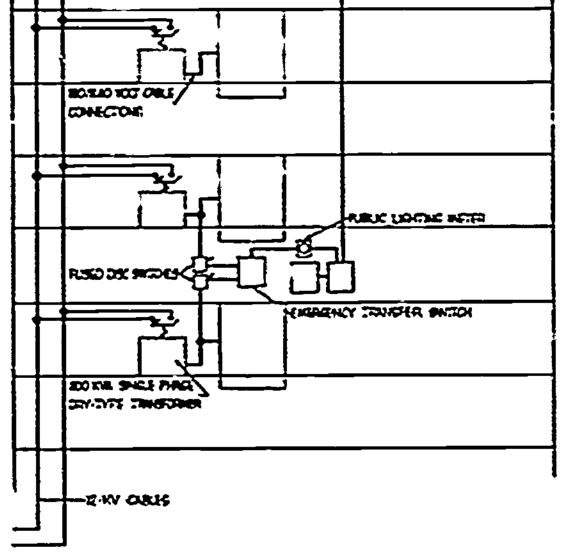
Architect and Engineer: Bertrand Goldberg Associates

Consulting Engineer (Heat Pumps): Ion Caloger Associates

Electrical Contractors: Apartment towers, Gerson Electric Construction Co.; office building, Fischbach-Moore & Morrissey, Inc.; underground and marina floor slab, Commercial Light Co.




Heated air recovered from the ceiling lighting fixtures may if necessary be reused by exterior-zone unitary air conditioners, which are located in the building core.




Power for the tower apartments is supplied at 12,000 volts to minimize space required for feeders. Transformers step voltage down to 120/240.

(Continued from Page 4)

**Information the architect should get from the local utility and the electrical contractor**

It is imperative that the architect base his economic studies for the all-electric building on complete and current information, covering rates, utility promotional practices, billing data from comparable buildings, etc. Obviously the economics will depend to some extent on local climate, code requirements for ventilation, and trade jurisdictions. But a critical element of the architect's economic study involves a detailed and complete analysis of utility company all-electric rate schedules, including those applying to the various categories of all-electric installations. The utility's sales representatives can furnish this data along with up-to-date billing data on all-electric buildings in the locality. Electrical contractors are a source of pertinent cost and practical installation information for the buildings on which billing data is available. A utility company engineer in conjunction with an electrical contractor can furnish additional information on transformer location, possibilities as to type of service, metering arrangements, utility charges to the customer for various types of service, etc.

**Striking a balance between energy costs and system complexity**

No heating-cooling installation should be more complex than the owner's economic situation warrants. It must be remembered, however, that economics also includes the rather intangible element of just what degree of operational simplicity the owner should have.

Automation, of course, can be more successfully applied to the all-electric building, with its known performance characteristics, than to any other type. But the degree of automation economically justifiable will depend upon the size of the installation and the nature of the occupancy. Many all-electric installations, such as room-by-room units in apartment buildings, are the ultimate in simplicity.

Unitary equipment packages of either single- or split-system type, whether air conditioners or heat pumps, often perform better than one large central system in handling the heating and cooling loads of a large building. The reasons are: (1) ducts may be less costly because of their smaller size and shorter runs; (2) balancing of the system is easier, and (3) installation is faster, allowing earlier building occupancy.

Even in larger buildings, larger packages of "built-up" equipment may be employed in a more flexible design, both to achieve more efficient utilization of direct electric energy and to allow the capture of "free heat" from outside sources and "waste heat" from building lights and equipment. Such systems still can be relatively simple.

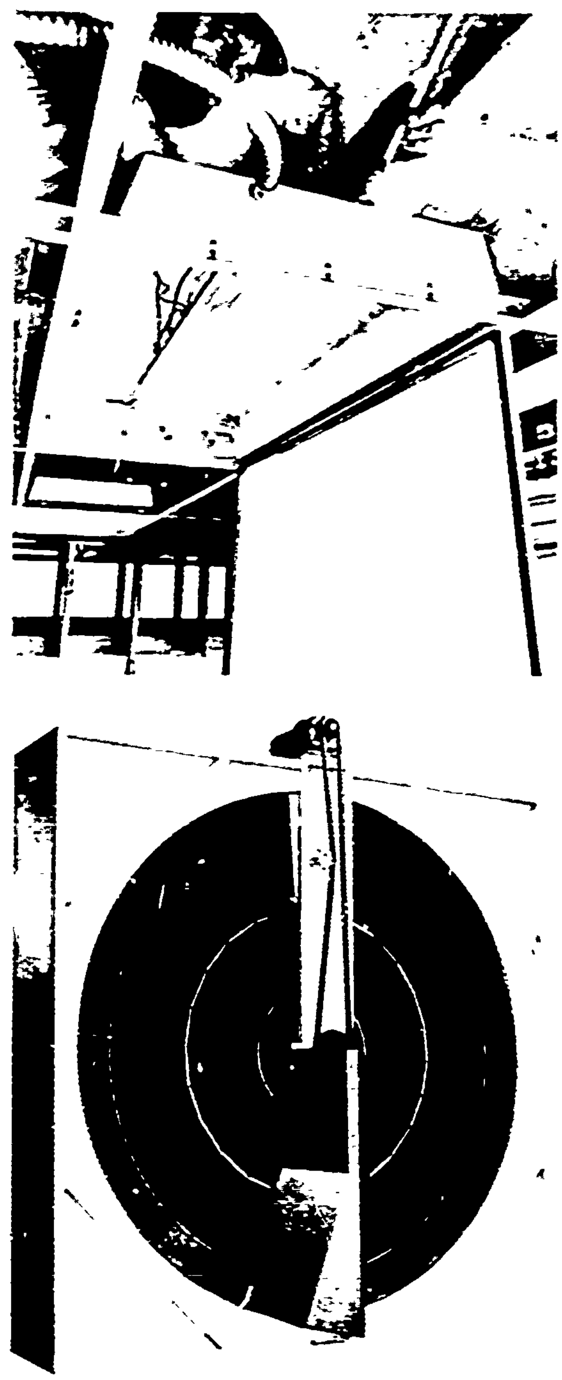
The larger-type central heat pumps that abstract "free heat" from outside air, even in the coldest weather, or from well water, very often allow a high "heat energy multiplication factor" all winter, making all-electric favorable even in areas where utility rates are not particularly attractive. With these systems, even the negative effects of piping and duct distribution system heat losses are relatively unimportant — they are small compared to the "free heat," and there are no standby losses. These systems require custom engineering of a rather specialized nature, but this know-how is available.

*Heat recovery:* The recovery of waste heat from electric ceilings and exhaust air is accomplished by means of simple heat-exchange systems. Heat storage systems (water tanks) for electric-hydronic systems that can use inexpensive off-peak power are basically simple. On the other hand, heat storage (water tank) systems used in conjunction with central heat pump installations to balance load peaks can be quite sophisticated and have to be exactly tailored to the building load profile on a custom engineering basis.

**The elements of all-electric space thermal conditioning**

The architect will appreciate that the all-electric approach to control of the thermal environment does not require: (1) any new understanding of complex thermodynamic concepts; (2) large and unpredictable space allocations, or (3) any more than usual provisions for noise and vibration (obviously, space heating by resistance units without fans is completely quiet). With the heat pump, the refrigerant flow is merely reversed when the cycle is changed from heating to cooling; when this is done, the evaporator becomes a condenser and vice versa. Other commonly used heat transfer processes used in building heating also are easy to understand.

It should be noted that there is a size limitation on packaged refrigeration equipment used for both heating and cooling — in the order of 100 tons — but this poses no problem.



**Two types of heat-recovery equipment are shown above. Top, non-refrigerated water runs through integral tubes of lighting fixture, rejecting lamp heat in the summer and providing free heat in the wintertime. Bottom, normally wasted energy from exhaust air can be picked up and transferred to fresh air by means of heat-recovery wheel.**

# A GLOSSARY OF ELECTRIC-ENVIRONMENTAL TERMS

The following *glossary* contains terms that are used in this text material and will be used consistently throughout later publications. They are arranged progressively (rather than alphabetically) in that understanding of the earlier-listed terms will facilitate understanding of those defined later:

Refrigerant — a compressible vapor which abstracts heat in going from liquid to vapor (evaporation) and gives up heat in going from vapor to liquid (condensation). The pressure at which this change of state must occur increases with the temperature at which condensation or its reverse, evaporation, occurs. For a given temperature, both occur at the same pressure, depending upon whether heat is added or abstracted.

Refrigeration compressor — a machine which increases the pressure of a refrigerant vapor by the action of a reciprocating piston in a cylinder or by a centrifugal impeller wheel.

Refrigerant condenser — a heat exchange device in which refrigerant vapor is liquified (condensed) by the removal of heat.

Refrigerant evaporator — a heat exchange device in which refrigerant liquid is vaporized (evaporated) by the absorption of heat. This is preceded by passing the liquid through a pressure-reducing flow device ahead of the evaporator.

Refrigeration system – a closed-flow system powered by electric energy in which a refrigerant is compressed, condensed, and expanded to produce cooling at a lower temperature level and rejection of heat at a higher temperature level. The power input to cause the compression shows up in the form of heat rejected at the higher temperature level.

Hermetic refrigeration system — a completely sealed system in which the electric motor driving the compressor is within the refrigerant vapor flow line from the evaporator and is cooled by these gases.

Air-conditioning system — in its *simplest* form, a refrigerant system combined with a forced-convection air flow system, all in a single package, with air blowing over the evaporator to cool the air, whence it is discharged directly into the space.

Central plant — the complete assemblage of inter-connected equipment and auxiliary systems, which functions to produce or transform energy for the purpose of distribution and use outside the plant.

Packaged equipment — equipment consisting of one or more completely factory-made, matched assemblies, including controls.

Unitary air-conditioning equipment or heat pump — an assembly of one or more matched equipment packages designed to include the complete refrigeration cycle, air heating and cooling function, and means for cooling the condenser.

Heat pump – a refrigeration system in which flow to the evaporator and the condenser can be reversed, thus allowing air or water passing through the evaporator (which normally cools) to be either cooled or heated.

Split system — unitary equipment in which the several packages are not within one factory-assembled enclosure but are remote from each other and are field connected.

Electric ceiling — ceiling containing lighting fixtures (and air outlets) with the lighting fixtures adaptable to heat recovery.

Heat energy multiplication factor — the ratio of the heating output of a heat pump to the electric energy equivalent required to power the system.

Cooling energy multiplication factor — the ratio of the cooling output of an air-conditioning system to the electric energy heat equivalent required to power the system.

Lighting-fixture heat — the portion of the electric energy supplied to a lighting fixture which does not produce visible light. (It must be remembered that all the light energy that goes into the space eventually is converted to heat.)

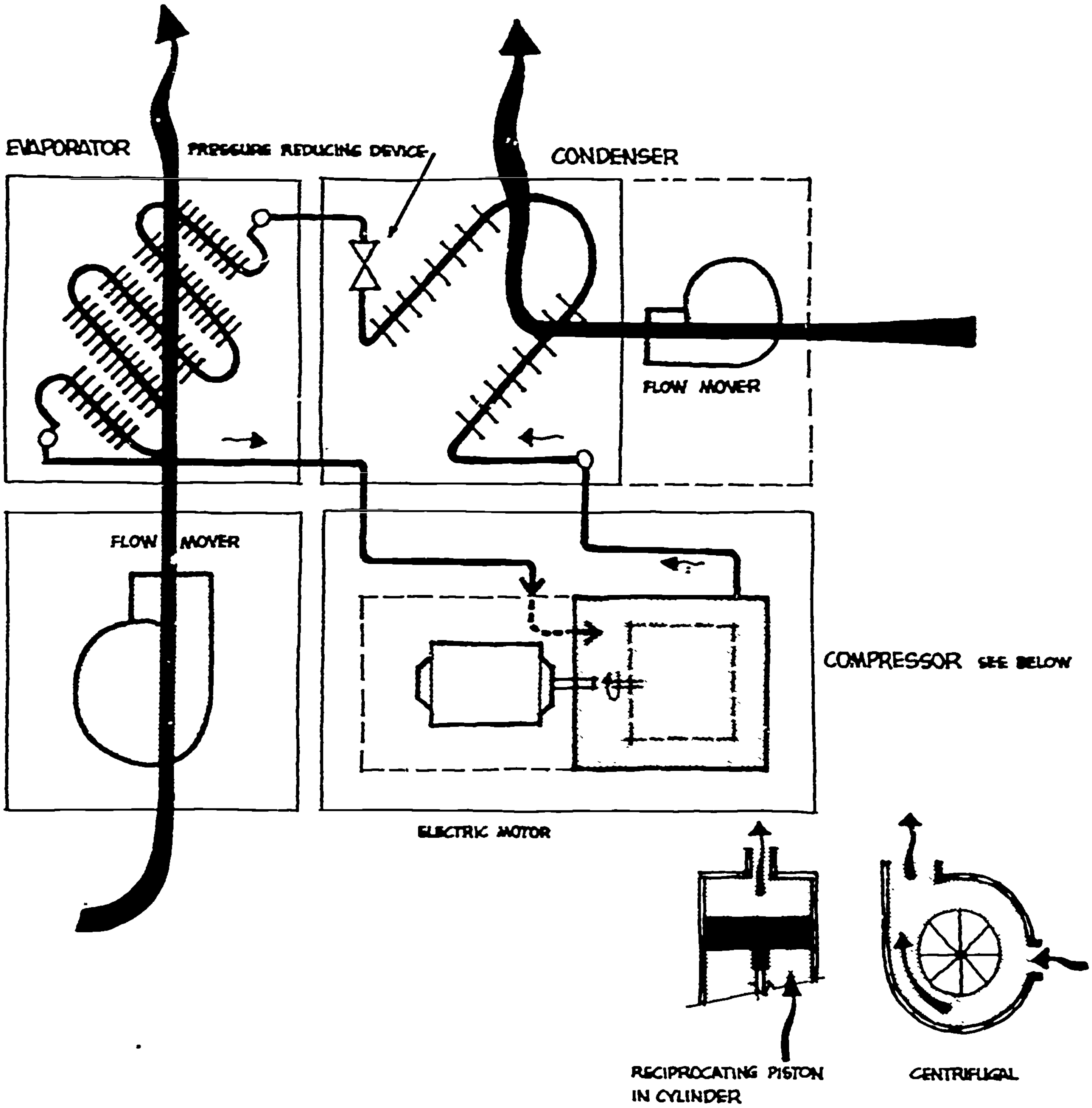
Direct processes (direct air conditioning, direct heating, and direct waste-heat recovery) — processes which always act on or affect space air. For example, air may stay in the space, be recirculated, or exhausted. If exhausted, the air will be discharged back into the same space, or other spaces, after being processed.

# SYSTEM-TYPES AVAILABLE FOR ENVIRONMENTAL CONTROL

## COOLING

Thermoelectric heating and cooling, which can produce either cooling or heating by direct electrical conversion, is still economically marginal, except for a few limited applications. When it does become practical it will be welcomed by architects and engineers alike since, without moving parts such as a compressor, it is a practically maintenance-free system. Meanwhile for all practical purposes cooling must be produced by motor-driven refrigeration (or by absorption or steam jet).

The simple block diagram on the following page explains all types of electric-drive compression refrigeration, whether used for central, chilled-water or direct-expansion air conditioners, or for heat pump operation. All possible combinations stem from this basic cycle.




Typical equipment employing the electric-powered refrigeration cycle: Variations on the refrigeration cycle are shown in the drawing, which depicts the cycle's four basic components. Commonly used types of air-conditioning equipment assembled from these components are:

Unitary single-package air conditioner – all of the elements in the diagram are included in a single factory-assembled enclosure. Flow mover for evaporator heat transfer is a fan.

Unitary split-system air conditioner – equipment is in two separate packages, each of which is factory assembled. Flow mover is a fan, which is in the same package as the evaporator. A compressor-condenser package combination is called a "condensing unit." An evaporator-blower package combination may also include the compressor, but in this case the condenser-fan unit is a separate package. The compressor also may be in the same enclosure as the evaporator and its fan, with an air-cooled condenser located remotely.

Packaged water chiller – contains the same basic elements as the above, except that the evaporator flow mover is a water pump. The combined elements do not produce air conditioning directly, hence the unit can not be called an air conditioner.

Unitary single-package heat pump – the same as the unitary air conditioner, except that the unit can operate with reversal of refrigerant flow through the evaporator-condenser piping. This allows the heat exchanger normally used for cooling to produce heating instead.

## HEATING

To help evaluate the various heating cycles for the systems used in the all-electric building, the elements used have been organized into the categories that appear below.

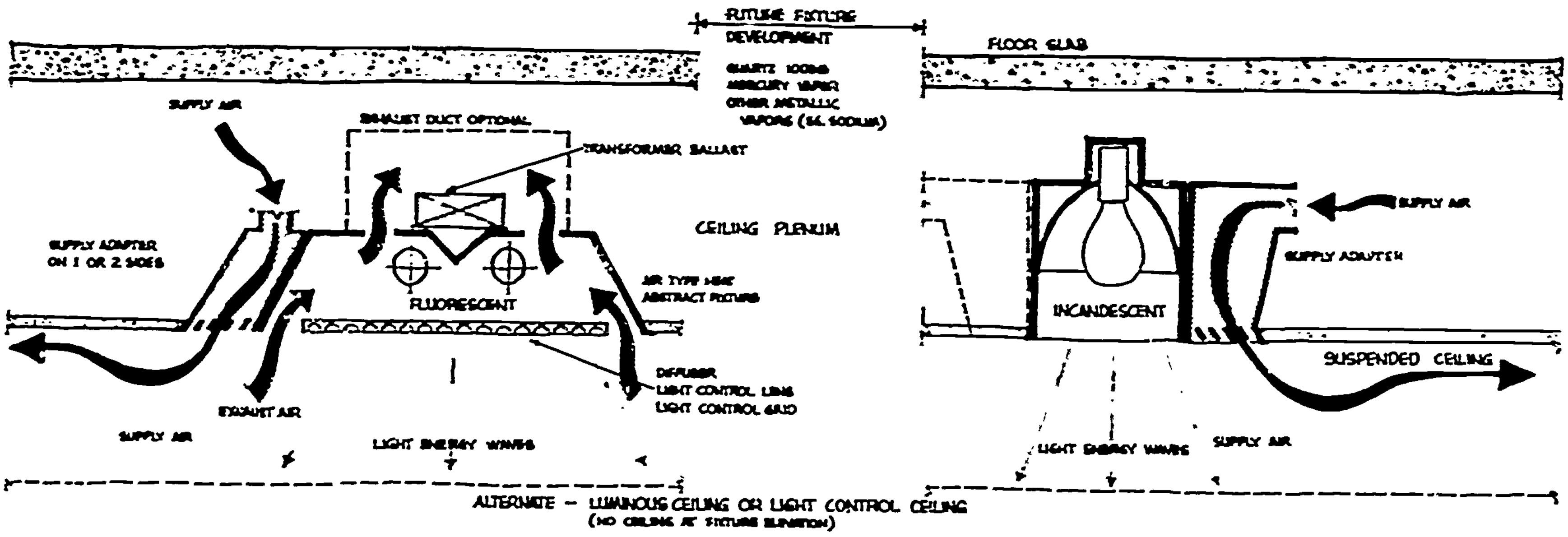
### Production of heat from electric energy

1. Direct input of heat into the room from packaged electric resistance-heating equipment.

a. Convection-type heaters.

(1) natural convection.
- baseboard (using a basic resistance element only or with added mass around the element for storage effect and to reduce the surface temperature of the element by use of metal or water storage).

(2) forced convection — recirculation of air within the space.
- free standing, floor mounted.
- ceiling suspended (including downblast unit heaters).
- wall mounted.
- through-wall with outside air-ventilation air connection (unit ventilator).
- add-on discharge heater for




**The electric ceiling: Principles are shown for integrating lighting fixtures and the outlets for supply and return air. Lighting fixture heat-recovery possibilities also are shown.**

- **The adapters may be simple add-on devices with outlets flush with the ceiling, or part of a standard combination.**
- **Water-cooled lighting fixtures using non-refrigerated water do not have air exhaustion through them.**
- **Heat abstraction features for both fluorescent and incandescent lighting fixtures must be considered integral with overall fixture design.**
- **All energy input to lighting fixtures eventually is turned into heat. Energy from light waves is absorbed by room surfaces and furnishings and converted to heat (this ranges from 5 per cent to 15 per cent of energy input).**

ductless air conditioning or heat-pump unit.

(3) forced convection—central air system.

— duct insert heater.

b. radiant heaters.

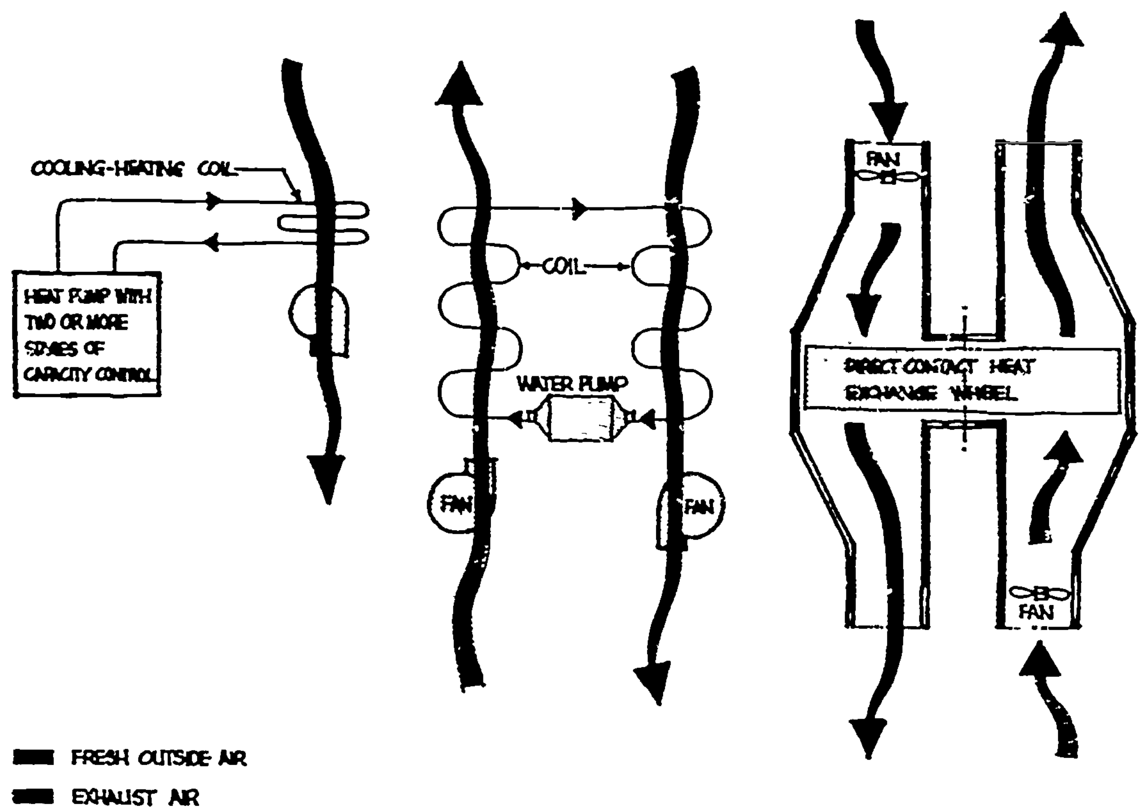
(1) low-temperature type.

— panels for surface, recessed or ceiling suspended, mounted on wall, floor, or ceiling.

(2) high-temperature type with directional reflector.

— ceiling mounted or suspended.

2. Indirect input of heat into the room by hot-water boiler with insert-type electric heaters.
3. Indirect input of heat into the room by use of building elements for heat storage — embedded resistance heating cable in floor, wall, or ceiling (radiant heating only).




**Economical tempering of air using central heat pump and heat-recovery systems.**

**Use of electric energy to pump heat to a higher temperature level for heating purposes by use of a heat pump**

1. Heat source from outside the building — outside air, well water, lake water, etc.
2. Heat sources from within the building.

a. lighting fixture heat (electric ceiling).

b. process and machinery room heat.

c. exhaust ventilation air.

d. rejected heat from zoned, unitary air-conditioning systems operating on cooling.

**Direct process use of waste heat to produce space heating effect**

1. Air used as the heat transfer medium.

a. lighting-fixture heat.

b. process and machinery room heat.

c. exhaust ventilation air (e.g., heat-recovery wheel to temper outside air).

d. heat rejected from zoned, air-cooled, unitary air-conditioning systems operating on cooling.

**Indirect process use of waste heat to produce space heating effect**

1. Water used as the heat transfer medium.

a. lighting-fixture heat (electric ceiling).

b. process and machinery heat.

c. exhaust ventilation air.

d. heat rejected from zoned, water-cooled, unitary air-conditioning systems operating on cooling.

**Storage devices (systems) to reduce peak electric demand**

1. Water storage tank for hot and/or chilled water. (Electric immersion heaters in a storage tank would be an integral element in such a system).

# CHOOSING A SYSTEM TO SUIT DESIGN REQUIREMENTS

The all-electric approach allows optimum system choice to suit any architectural design concept. Room-by-room and zone-by-zone all-electric environmental control systems should always be considered for any building, regardless of size, since they have proved successful in innumerable buildings of every type. However, the architect, for a variety of reasons, may want to look beyond these systems to the more sophisticated smaller central systems in multiple, using unitary equipment and/or combinations of packaged equipment. It can be demonstrated that this approach offers the architect both planning flexibility and aesthetic freedom, while retaining system flexibility.

Advantages of the large package (unitary) equipment to the architect and his consulting engineer, related to their respective professional responsibilities, are: (1) completely engineered, factory-assembled packages; (2) total system application guidance information from the manufacturer with maximum back-up in regard to performance, and (3) with all-electric equipment, availability of service and maintenance from a single source, the electrical contractor.

While in the past architects may have had some poor experience with unitary equipment for more sophisticated "custom-design" heating and air-conditioning systems, the situation has changed. Now there is greater manufacturer field-testing of systems, including those of greater complexity with related standardization of compatible control systems for a wide range of applications. This gives the architect wide flexibility in design possibilities for integrating many suitable systems into his overall building design concepts.

The unitary-package approach has a number of operational and design advantages, among which are: (1) smaller building modules for zoning permit more exact temperature control for these modules, with less waste energy than central systems employing less zoning; (2) more efficient space utilization is possible for the energy transformation equipment (heating, refrigeration) since the package sizes can be chosen to suit the space arrangement of a given floor plan and the niches available for equipment installation, and (3) improved thermal comfort is possible because the selection of terminal components as to type and location can be more nearly tailored to the nature of the building heat gain and losses. This last advantage, of course, applies to a number of all-electric systems, though there may be more latitude with the package approach.

One of the most attractive features of all-electric environmental systems is that they are much less dominant in the overall architectural design than the more traditional systems that depend on a highly complex network of ducts and pipe runs above the ceiling, at exterior walls, and in vertical shafts. There is no need for expensive structural adjustments to accommodate such mechanical services, especially with the unitary approach, in which the duct and pipe runouts can be kept small or eliminated.

### The multi-functional "electric ceiling"

The "electric ceiling" does considerably more than a conventional suspended ceiling and — most importantly — it does it more inconspicuously. Through especially designed light control media, the electric ceiling provides high levels of illumination comfortably. It removes waste heat from lamps so that this heat does not create an uncomfortable "radiant" effect from the ceiling (especially true for higher footcandle levels) and prevents convected heat from lamps from reaching room space, convected heat that might be difficult to negate with cool supply room air without creating drafts in the room. It may recapture the waste heat from lamps for reutilization in the heating and air-conditioning system.

The lighting can be functional or decorative or both. The light from the ceiling may be controlled so as to illuminate the horizontal plane, the walls, and the ceiling itself. The light can also be kept off any of these planes if the architectural design calls for it. Varying degrees of acoustical sound absorption can be integrated with the electric ceiling in a number of ways.

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